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FOR NATURALISTIC RESEARCH AND ENVIRONMENTAL STUDIES

Charadrius dubius curonicus Gmelin, 1789 - Lybia, Tripoli, Alhadba

Study of birds in Libya. The coast line of Libya has different kinds of wetlands such as islands, lagoons, lakes, salt marshes and bays (Defos et al., 2001). These habitats provide foraging sites and good shelters for migratory birds during their migration from Europe and Asia to Africa and back. Moreover, some of these sites provide residential and nesting ground for some species. However, Libya, with its relatively dry climate, is perceived as having comparatively few wetlands and waterbirds. It is also, ornithologically speaking, the least known country of Mediterranean Africa (Smart et al., 2006). Recent reviews list 317 species, of which approximately 25% are breeders (Toschi, 1969; Bundy, 1976). They account for about 75% of the avifauna of Libya, passing from the western Palearctic region to their southern winter quarters. Some of these also occur here as breeding species. There are many other papers reporting about waterbirds (e.g. Gaskell, 2005; Smart et al., 2006; Hering, 2009; Essghaier et al., 2009; Etayeb & Essghaier, 2012; Etayeb et al., 2013a,b and 2014), as well as some unpublished reports (e.g. Defos du Rau et al., 2001, Etayeb, 2002). However, there are only few experienced ornithologists in Libya, which has resulted in deficiency of information on Libyan birds during last three decades. However during the last decade, interest in the Libyan wetlands has increased. In the mid-nineties the UNEP Mediterranean Action Plan (MAP), adopted a "Protocol concerning Special Protected Areas (SPA) and Biological Diversity in the Mediterranean". Annex II of the Protocol includes a "List of Endangered or Threatened Species", including 15 waterbirds, for which a Bird Action Plan has been prepared (UNEP MAPRAC/SPA, 2003). Libya was involved in the framework of the Barcelona Convention and has also ratified the Ramsar Convention, and in 2002, two wetlands in the Jebel Akhdar area were designated. In 2005, Libya signed the African-Eurasian Waterbird Agreement (AEWA), under the umbrella of the Convention on Migratory Species (CMS) (Smart et al., 2006). Consequently, a regular wintering water-bird census for Libyan wetlands has launched in year 2005.

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© Photos copyright of the authors. Off: Lybia, Ain Ashaghigha, photo K.S. Etayeb. Middle: Gaber Own, photo K.S. Etayeb. Down: Common Sandpiper, *Actitis hypoleucos* (Linnaeus, 1758), Lybia, Tripoli, Alhadba, photo Bouras. Cover: Little Ringed plover, *Charadrius dubius curonicus* Gmelin, 1789, Lybia, Tripoli, Alhadba, photo Bouras.

Preface

The Malacological Pontine Meeting, San Felice Circeo, Italy

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As part of the knowledge of the biodiversity of the pontine area and in particular of the Circeo National Park, in 2007 the writer, then director of the "Museo Civico del Mare e della Costa Marcello Zei" of Sabaudia, thought appropriate to include as one of the institutional activities of the museum the deepening of research at malacological level, hitherto restricted only to a few scientific papers related to molluscs of Mount Circeo (Lepri, 1909), of the area of Terracina (Sacchi & Girod, 1968), with some footnotes to broader works on the biodiversity of coastal lakes of Latium, as in the case of the Paola (or Sabaudia) Lake (Brunelli & Cannicci, 1934) in which is also described a new species (*Rissoa sabaudiae* Coen, 1934 never reported again) or parts of research related to marine areas overlooking the coast and the Pontine islands (Gravina et al., 1992) (Figs. 1, 2).

Equally sporadical are the reports on fossil molluscs: regarding Mount Circeo, *Strombus bubonius* Lamarck, 1822 and *Tritonidea viverrata* Kiener, 1757 were reported by Blanc (1940) in the Guttari Cave and Durante & Settepassi (1974) have reported some species found in the "Grotta delle Capre". The malacofauna of the fossil dunes of the islands of Ponza and Ventotene (Pontine Archipelago) was finally studied by Sacchi (1952).

With these premises in May 2007 was therefore organized the "Prima Giornata di Studi Malacologici Pontini" in which, among other things Danilo Vani

presented the first report of *Gibbula nebulosa* (Philippi, 1841) in the Pontine coast. In subsequent years, given the interest of Italian malacologists for this initiative, the name of the event changed to "Convegno Malacologico Pontino" arranged in two days of study and funded by the Lazio Region through the "Museo Civico del Mare e della Costa" of Sabaudia, which remained until 2012, the place of the event , replaced in 2013 (and since October 2014) both as funding agency as seat by the Municipality of San Felice Circeo, together with the Pontine Naturalistic Malacological Association "Malakos 2002" as co-financing organization.

In the seven editions (2007-2013) of the Meeting implemented to date, numerous speakers both professionals of academic origin and amateurs have dealt with the most important topics regarding malacology from the point of view of systematics, ecology, biogeography, molecular biology, paleontology, etc..., by several reports, some of which have resulted both in scientific and popular publications.

There have been numerous reports that have dealt with topics of systematics and biogeography concerning the Pontine Area, and in particular: the first report of *Gibbula nebulosa* (Philippi, 1841) in the Pontine coast (Danilo Vani, VII Meeting) the study of land molluscs of Mount Circeo (Alessandro Hallgass & Angelo Vannozzi, II Meeting) and of the islands Ventotene and Santo Stefano (Alessan-

Figure 1. Mount Circeo (photo S. Moncado).

Figure 2. Pontine Archipelago (photo S. Moncado).

dro Hallgass & Angelo Vannozzi, VI Meeting), the study of molluscs of the pontine dunes (Antonio Incandela, II Meeting), preliminary (Andrea Bassi, III Meeting) and final (Bruno Fumanti, VII Meeting) reports on the marine molluscs of Zannone, the distribution of the genus *Onoba* H. & A. Adams, 1852 (Rissoidae) in pontine waters (Bruno Amati & Italo Nofroni, IV Meeting), a study of nudibranchs from "Canale Romano" of the Paola Lake (Giulia Furfaro, Armando Macali & Paolo Mariottini, V Meeting), the study of molluscs in the sands of beach nourishment on the coast of Terracina (Luigi Giannelli, VII Meeting), the study of the Mollusca from the "Secca dei Mattoni", Pontine Archipelago (Fabio Crocetta, Giuseppe Fasulo, Italo Nofroni and Arturo Facente, IV Meeting) and the study of the Pleistocene continental molluscs in the Pontine Plain (Daniele Gianola, III Meeting).

It follows therefore that these regular meetings have contributed in some way to increase our knowledge of biodiversity, even if limited to malacofauna, of this area, which includes among other things a National Park in many ways unique in the world.

ACKNOWLEDGEMENTS

The Author and the organizers of the Seventh Malacological Pontine Meeting wish to thank the Municipality of San Felice Circeo and in particular the Mayor Giovanni Petrucci, the Chairman of the Education Egidio Calisi, the delegate of the Mayor Franco Domenichelli and "Malakos 2002" (Associazione Macologica Naturalistica Pontina) in the person of its president Claudio Buccarella for the financial support to the realization of the meeting.

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Contribution to the knowlegde of the benthic molluscan thanatocoenosis of Zannone Island (Pontine Archipelago, Latium, Italy)

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ABSTRACT   During the period May 2008-September 2012 were investigated some sediment samples collected by scuba diving at various depths in the waters surrounding the Island of Zannone (Pontine Archipelago, Latium, Italy). Altogether 280 taxa belonging to 156 genera were identified.

INTRODUCTION

This study originates from the collaboration of many malacologists, professional and otherwise, who have joined a project for the study of marine Mollusca of the Island of Zannone. The project has been realized on proposal of "Museo Civico del Mare e della Costa" in Sabaudia with funding from the "Regione Lazio". The idea of studying the marine Mollusca of Zannone was pondered on occasion of an excursion organized at the conclusion of the "Second Malacological Pontine Meeting" held in Sabaudia on May 2008.

A quick analysis of some sediment samples taken during scuba diving carried out by some participants revealed a malacofauna relatively rich so much to suggest a project for a more comprehensive and careful study. The result was the creation of a working group organized and coordinated by some members of MALAKOS 2002 (Associazione Malacologica Naturalistica Pontina), who, thanks to the funds received, have been able to carry out several samplings of bottom sediments and then distribute the collected material to all the research participants.

The broad involvement of many malacologists, professional and otherwise, who collaborated in this research, even if preliminary, is the first concerning an island in the Pontine Archipelago and this makes us hope in the possibility of achieving further malacological studies on the coasts, the lakes and island of the Pontine region.

The writer of this work even participating actively in the organization of the research has merely reorganized what elaborated by all the participants, listed below in alphabetic order: Silvia Alfinito (Sabaudia, Italy), Andrea Bassi (Ravenna, Italy), Enzo Campani (Livorno, Italy), Luigi Giannelli (Terracina, Italy), Saverio Moncado (Latina, Italy), Italo Nofroni (Rome, Italy), Marco Oliverio (Rome, Italy), Angela Pierullo (Rome, Italy), Ermanno Quaggiotto (Vicenza, Italy), Carlo Sbrana (Pisa, Italy), Peter Sossi (Mondovì, Italy), Piergiorgio Trillò (Rome, Italy); Daniele Trono (Copertino, Italy), Danilo Van (Rome, Italy), Angelo Vannozzi (Rome, Italy).

MATERIAL AND METHODS

The Pontine Islands are an archipelago in the Tyrrhenian Sea off the west coast of Italy. The islands were collectively named after the largest island in the group, Ponza; the other islands in the archipelago are Palmarola, Zannone, Gavi, Ventotene and Santo Stefano.

Zannone is the most northern island of the archipelago. Uninhabited, since 1979 is part of the National Park of Circeo. It is a "green island", covered with a typical Mediterranean maquis. The Island of Zannone has an area of approximately 106 ha and is located 6 miles from the Island of Ponza, on which it administratively depends. Altogether 8 grit samples were examined:

2008, May: 40°58'28" E; 13°09'49" N
-18 m, -20 m
2009, June: 40°57'55" E; 13°02'59" N
-20m, -26m, -50m
2011, October: 40°57'54" E; 13°03'10" N
-18m, -20 m
2012, September: 40°07'55" E; 13°02'46" N
-20 m

The nomenclature of the species has been updated according to WoRMS Editorial Board (2014).

RESULTS

The analysis of samples distributed to the research participants led to the identification of 280 taxa (Table 1).

	Polypla-cophora	Gastro-poda	Bivalvia	Scapho-poda	Total
Ordines	1	9	10	1	21
Familiae	3	65	22	1	91
Genera	3	110	42	1	156
Species	5	221	53	1	280

Table 1. Diversity of the fauna of molluscs of Zannone Island (Ponthine Archipelago, Latium, Italy).

Taxonomic list

Classis POLYPLACOPHORA Gray, 1821
Ordo CHITONIDA Thiele, 1909

Familia CHITONIDAE Rafinesque, 1815

Genus *Chiton* Linnaeus, 1758
  Chiton (*Rhyssoplax*) *corallinus* Risso, 1826
  Chiton (*Rhyssoplax*) *olivaceus* Spengler, 1797

Familia ISCHNOCHITONIDAE Dall, 1889

Genus *Ischnochiton* Gray, 1847
  Ischnochiton (*Ischnochiton*) *rissoi* (Payraudeau, 1826)

Familia ACANTHOCHITONIDAE Pilsbry, 1893

Genus *Acanthochitona* Gray, 1821
  Acanthochitona crinita (Pennant, 1777)
  Acanthochitona fascicularis (Linnaeus, 1767)

Classis GASTROPODA Cuvier, 1797
Ordo PATELLOGASTROPODA Lindenberg, 1986

Familia PATELLIDAE Rafinesque, 1815

Genus *Patella* Linnaeus, 1758
  Patella caerulea Linnaeus, 1758
  Patella rustica Linnaeus, 1758
  Patella ulyssiponensis Gmelin, 1791

Ordo VETIGASTROPODA Salvini-Plawen, 1980

Familia FISSURELLIDAE Fleming, 1822

Genus *Diodora* J.E. Gray, 1821
  Diodora gibberula (Lamarck, 1822)
  Diodora graeca (Linnaeus, 1758)

Genus *Emarginula* Lamarck, 1801
  Emarginula adriatica O.G. da Costa, 1830
  Emarginula huzardii Payraudeau, 1826
  Emarginula octaviana Coen, 1939
  Emarginula punctulum Piani, 1980
  Emarginula tenera Locard, 1892

Familia SCISSURELLIDAE Gray, 1847

Genus *Scissurella* d'Orbigny, 1824
  Scissurella costata d'Orbigny, 1824

Familia HALIOTIDAE Rafinesque, 1815

Genus *Haliotis* Linnaeus,1758
  Haliotis tuberculata lamellosa Lamarck, 1822
  Haliotis tuberculata tuberculata Linnaeus, 1758

Familia TROCHIDAE Rafinesque, 1815

Genus *Clanculus* Monfort, 1810
  Clanculus corallinus (Gmelin, 1791)
  Clanculus cruciatus (Linnaeus, 1758)
  Clanculus jussieui (Payraudeau, 1826)

Genus *Jujubinus* Monterosato, 1884
  Jujubinus exasperatus (Pennant, 1777)
  Jujubinus gravinae (Dautzenberg, 1881)
  Jujubinus striatus (Linnaeus, 1758)

Genus *Gibbula* Risso, 1826
  Gibbula ardens (Salis Marschlins, 1793)
  Gibbula guttadauri (Philippi, 1836)
  Gibbula racketti (Payraudeau, 1826)
  Gibbula turbinoides (Deshayes, 1835)
  Gibbula umbilicaris (Linnaeus, 1758)
  Gibbula varia (Linnaeus, 1758)

Familia CALLIOSTOMATIDAE Thiele, 1924

Genus *Calliostoma* Swainson, 1840
  Calliostoma zizyphinum (Linnaeus, 1758)

Familia TURBINIDAE Rafinesque, 1815

Genus *Bolma* Risso, 1826
  Bolma rugosa (Linnaeus, 1767)

Familia SKENEIDAE Clark, 1851

Genus *Skenea* Fleming, 1825
  Skenea catenoides (Monterosato, 1877)

Genus *Dikoleps* Hoisaeter, 1968
  Dikoleps marianae Rubio, Dantart et Luque, 1998
  Dikoleps templadoi Rubio, Dantart et Luque, 2004
  Dikoleps umbilicostriata (Gaglini, 1987)

Genus *Skeneoides* Warén, 1992
  Skeneoides exilissima (Philippi, 1844)

Fig. 1. Zannone Island (Ponthine Archipelago, Latium, Italy).

Familia CHILODONTIDAE Wenz, 1938

Genus *Danilia* Brusina, 1865
  Danilia tinei (Calcara, 1839)

Familia PHASIANELLIDAE Swainson, 1840

Genus *Tricolia* Risso, 1826
  Tricolia pullus (Linnaeus, 1758)
  Tricolia speciosa (von Mühlfeldt, 1824)
  Tricolia tenuis (Michaud, 1829)

Familia COLLONIIDAE Cossmann, 1917

Genus *Homalopoma* Carpenter, 1864
  Homalopoma sanguineum (Linnaeus, 1758)

Ordo NERITIMORPHA Golikov et Starobogatov, 1975

Familia NERITIDAE Rafinesque, 1815

Genus *Smaragdia* Issel, 1869
  Smaragdia viridis (Linnaeus, 1758)

Ordo CAENOGASTROPODA Cox, 1960

Familia CERITHIIDAE Fleming, 1822

Genus *Cerithium* Bruguière, 1789
  Cerithium lividulum Risso, 1826
  Cerithium renovatum Monterosato, 1884
  Cerithium vulgatum Bruguière, 1792

Genus *Bittium* Gray, 1847
  Bittium latreillii (Payraudeau, 1826)

Bittium reticulatum (da Costa, 1778)
Bittium submammillatum (De Rayneval et Ponzi,1854)

Familia PLANAXIDAE Gray, 1850

Genus *Fossarus* Philippi, 1841
Fossarus ambiguus (Linnaeus, 1758)

Familia SILIQUARIIDAE Anton, 1838

Genus *Tenagodus* Guettard, 1770
Tenagodus obtusus (Schumacher, 1817)

Familia TURRITELLIDAE Lovén, 1847

Genus *Turritella* Lamarck,1799
Turritella communis Risso, 1826
Turritella turbona Monterosato, 1877

Familia TRIPHORIDAE J.E. Gray, 1847

Genus *Marshallora* Bouchet, 1985
Marshallora adversa (Montagu, 1803)

Genus *Monophorus* Grillo, 1877
Monophorus perversus (Linnaeus, 1758)

Genus *Metaxia* Monterosato, 1884
Metaxia metaxa (Delle Chiaje, 1828)

Familia CERITHIOPSIDAE H. Adams et A. Adams, 1853

Genus *Cerithiopsis* Forbes et Hanley, 1850
Cerithiopsis barleei Jeffreys,1867
Cerithiopsis jeffreysi Watson,1885
Cerithiopsis tubercularis (Montagu, 1803)

Genus *Nanopsis* Cecalupo et Robba, 2010
Nanopsis nana (Jeffreys, 1867)

Genus *Krachia* Baluk, 1975
Krachia cylindrata (Jeffreys, 1885)

Familia EPITONIIDAE Berry, 1910

Genus *Epitonium* Röding, 1798
Epitonium clathrus (Linnaeus, 1758)

Familia EULIMIDAE Philippi, 1853

Genus *Ersilia* Monterosato, 1872
Ersilia mediterranea (Monterosato,1869)

Genus *Parvioris*Warén, 1981
Parvioris ibizenca (Nordsieck, 1968)

Genus *Sticteulima* Laseron, 1955
Sticteulima jeffreysiana (Brusina, 1869)

Genus *Vitreolina* Monterosato, 1884
Vitreolina curva (Monterosato, 1874)
Vitreolina philippi (de Rayneval et Ponzi, 1854)

Familia LITTORINIDAE Children, 1834

Genus *Melarhaphe* Menke, 1828
Melarhaphe neritoides (Linnaeus, 1758)

Familia CINGULOPSIDAE Fretter et Patil, 1958

Genus *Eatonina* Thiele, 1912
Eatonina ochroleuca (Brusina,1869)
Eatonina pumila (Monterosato, 1884)

Genus *Tubbreva* Ponder, 1965
Tubbreva micrometrica (Aradas et Benoit, 1876)

Familia RISSOIDAE J.E.Gray, 1847

Genus *Rissoa* Desmarest, 1814
Rissoa auriscalpium (Linnaeus, 1758)
Rissoa guerinii Récluz, 1843
Rissoa lia (Monterosato, 1884)
Rissoa monodonta Philippi, 1836
Rissoa rodhensis Verduin, 1985
Rissoa scurra (Monterosato, 1917)
Rissoa similis Scacchi, 1836
Rissoa variabilis (von Mühlfeldt, 1824)
Rissoa ventricosa Desmarest, 1814
Rissoa violacea Desmarest, 1814

Genus *Pusillina* Monterosato, 1884
Pusillina inconspicua (Alder, 1844)
Pusillina philippi (Aradas et Maggiore, 1844)
Pusillina radiata (Philippi, 1836)

Genus *Setia* H. Adams et A. Adams, 1852
Setia ambigua (Brugnone, 1873)
Setia maculata (Monterosato, 1869)

Genus *Alvania* Risso, 1826
    Alvania cfr. *aeoliae* Palazzi, 1988
    Alvania beanii (Hanley in Thorpe, 1844)
    Alvania cimex (Linnaeus, 1758)
    Alvania cancellata (da Costa, 1778)
    Alvania clathrella (Seguenza, 1903)
    Alvania claudioi Buzzurro et Landini, 2007
    Alvania dictyophora (Philippi, 1844)
    Alvania discors (Allan, 1818)
    Alvania geryonia (Nardo, 1847)
    Alvania hirta (Monterosato, 1844)
    Alvania hispidula (Monterosato, 1844)
    Alvania lineata Risso, 1826
    Alvania lucinae Oberling, 1970
    Alvania mamillata Risso, 1826
    Alvania scabra (Philippi, 1844)
    Alvania settepassii Amati et Nofroni, 1985
    Alvania sororcula Granata-Grillo, 1877
    Alvania subareolata Monterosato, 1869
    Alvania subcrenulata (Bucquoy, Dautzenberg et Dollfus, 1884)
    Alvania tenera (Philippi, 1844)

Genus *Crisilla* Monterosato, 1917
    Crisilla cfr. *aartseni* (Verduin, 1984)
    Crisilla beniamina (Monterosato, 1884)
    Crisilla marioni Fasulo et Gaglini, 1987
    Crisilla semistriata (Montagu, 1808)

Genus *Manzonia* Brusina, 1870
    Manzonia crassa (Kanmacher, 1798)

Genus *Obtusella* Cossmann, 1921
    Obtusella intersecta (S.Wood, 1857)

Genus *Onoba* H. Adams et A. Adams, 1852
    Onoba dimassai Amati et Nofroni, 1991

Genus *Peringiella* Monterosato, 1878
    Peringella elegans (Locard, 1892)

Genus *Rissoina* d'Orbigny, 1840
    Rissoina bruguieri (Payraudeau, 1826)

Familia BARLEEIDAE J.F. Gray, 1857

Genus *Barleeia* W.Clark, 1853
    Barleeia unifasciata (Montagu,1803)

Familia CAECIDAE Gray, 1850

Genus *Caecum* Fleming, 1813
    Caecum auriculatum de Folin, 1868
    Caecum clarkii Carpenter, 1859
    Caecum subannulatum de Folin, 1870
    Caecum trachea (Montagu, 1803)

Familia HYDROBIIDAE Stimpson, 1865

Genus *Hydrobia* Hartmann, 1821
    Hydrobia acuta (Draparnaud, 1805)

Familia TORNIDAE Sacco, 1896

Genus *Tornus* Turton et Kingston, 1830
    Tornus subcarinatus (Montagu, 1803)

Familia TRUNCATELLIDAE J.E. Gray, 1840

Genus *Truncatella* Risso, 1826
    Truncatella subcylindrica (Linnaeus, 1767)

Familia VERMETIDAE Rafinesque, 1815

Genus *Petaloconchus* Lea, 1843
    Petaloconchus glomeratus (Linnaeus, 1758)

Genus *Vermetus* Daudin, 1800
    Vermetus granulatus (Gravenhorst,1831)
    Vermetus rugulosus Monterosato, 1878
    Vermetus triquetrus Bivona-Bernardi, 1832

Familia APORRHAIDAE J.E. Gray, 1850

Genus *Aporrhais* da Costa, 1778
    Aporrhais pespelecani (Linnaeus, 1758)

Familia VANIKORIDAE J.E. Gray, 1840

Genus *Megalomphalus* Brusina, 1871
    Megalomphalus azonus (Brusina, 1865)
    Megalomphalus disciformis (Granata-Grillo, 1877)

Familia CALYPTRAEIDAE Lamarck, 1809

Genus *Crepidula* Lamarck, 1799
    Crepidula unguiformis Lamarck, 1822

Genus *Calyptraea* Lamarck, 1799
    Calyptraea chinensis (Linnaeus, 1758)

Familia VELUTINIDAE J.E. Gray, 1840

Genus *Lamellaria* Montagu, 1815
    Lamellaria perspicua (Linnaeus, 1758)

Familia CYPRAEIDAE Rafinesque, 1815

Genus *Luria* Jousseaume, 1884
    Luria lurida (Linnaeus, 1758)

Familia NATICIDAE Guilding, 1834

Genus *Euspira* Agassiz in Sowerby, 1837
    Euspira nitida (Donovan, 1804)

Genus *Notocochlis* Powell, 1933
    Notocochlis dillwynii (Payraudeau, 1826)

Familia ATLANTIDAE Rang, 1829

Genus *Atlanta* Lesueur, 1817
    Atlanta brunnea J.E.Gray,1850
    Atlanta peronii Lesueur, 1817

Familia MURICIDAE Rafinesque, 1815

Genus *Bolinus* Pusch, 1837
    Bolinus brandaris (Linnaeus, 1758)

Genus *Hexaplex* Perry,1810
    Hexaplex trunculus (Linnaeus, 1758)

Genus *Ocinebrina* Jousseaume, 1880
    Ocinebrina aciculata (Lamarck, 1822)
    Ocinebrina edwardsii (Payraudeau, 1826)
    Ocinebrina reinai Bonomolo et Crocetta, 2012

Genus *Muricopsis* Bucquoy et Dautzenberg, 1882
    Muricopsis cristata (Brocchi, 1814)

Genus *Coralliophila* H. Adams et A. Adams,, 1853
    Coralliophila meyendorffii (Calcara, 1845)

Familia MARGINELLIDAE Fleming, 1828

Genus *Granulina* Jousseaume, 1888
    Granulina boucheti Gofas, 1992
    Granulina mediterranea Landau, La Perna et
    Marquet, 2006
    Granulina marginata (Bivona, 1832)
    Granulina occulta (Monterosato, 1869)

Genus *Volvarina* Hinds, 1844
    Volvarina mitrella (Risso, 1826)

Familia CYSTISCIDAE Stimpson, 1865

Genus *Gibberula* Swainson, 1840
    Gibberula miliaria (Linnaeus, 1758)
    Gibberula philippii (Monterosato, 1878)
    Gibberula turgidula (Locard et Caziot, 1900)

Familia MITRIDAESwainson, 1829

Genus *Mitra* Lamarck, 1798
    Mitra cornicula (Linnaeus, 1758)

Familia COSTELLARIIDAE Mac Donald, 1860

Genus *Vexillum* Röding, 1798
    Vexillum ebenus (Lamarck, 1811)
    Vexillum savignyi (Payraudeau, 1826)
    Vexillum tricolor (Gmelin, 1791)

Familia BUCCINIDAE Rafinesque, 1815

Genus *Euthria* Gray, 1850
    Euthria cornea (Linnaeus, 1758)

Genus *Chauvetia* Monterosato, 1884
    Chauvetia mamillata (Risso, 1826)
    Chauvetia procerula (Monterosato, 1889)
    Chauvetia turritellata (Deshayes, 1835)
    Chauvetia sp.

Genus *Pisania* Bivona-Bernardi, 1832
    Pisania striata (Gmelin, 1791)

Genus *Pollia* J.E. Gray, 1834
    Pollia dorbignyi (Payraudeau, 1826)
    Pollia scabra Locard, 1892
    Pollia scacchiana (Philippi, 1844)

Familia NASSARIIDAE Iredale, 1916

Genus *Nassarius* Duméril, 1805
    Nassarius nitidus Jeffreys, 1867

Genus *Ciclope* Risso, 1826
    Ciclope neritea (Linnaeus, 1758)

Familia COLUMBELLIDAE Swainson, 1840

Genus *Columbella* Lamarck, 1799
    Columbella rustica (Linnaeus, 1758)

Familia FASCIOLARIIDAE J.E. Gray, 1853

Genus *Fusinus* Rafinesque, 1815
    Fusinus pulchellus (Philippi, 1844)
    Fusinus syracusanus (Linnaeus, 1758)

Familia CONIDAE Fleming, 1822

Genus *Conus* Linnaeus, 1758
    Conus ventricosus Gmelin,1791

Familia HORAICLAVIDAE Bouchet, Kantor, Sysoev et Puillandre, 2011

Genus *Haedropleura* Bucquoy, Dautzenberg et Dollfus, 1883
    Haedropleura secalina (Philippi, 1844)

Familia CLATHURELLIDAE H. Adams et A. Adams, 1858

Genus *Clathromangelia* Monterosato, 1844
    Clathromangelia granum (Philippi, 1844)

Familia MITROMORPHIDAE Casey, 1904

Genus *Mitromorpha* Carpenter, 1865
    Mitromorpha mediterranea Milfsud, 2001
    Mitromorpha melitensis (Milfsud, 1993)

Familia MANGELIIDAE P. Fischer,1883

Genus *Bela* J.E. Gray, 1847
    Bela menkhorsti van Aartsen, 1988

Genus *Mangelia* Risso, 1826
    Mangelia multilineolata (Deshayes, 1835)
    Mangelia striolata Risso, 1826
    Mangelia taeniata (Deshayes, 1835)
    Mangeria unifasciata (Deshayes, 1835)

Familia RAPHITOMIDAE Bellardi, 1875

Genus *Raphitoma* Bellardi, 1847
    Raphitoma densa (Monterosato, 1884)
    Raphitoma echinata (Brocchi, 1814)
    Raphitoma horrida (Monterosato, 1884)
    Raphitoma leufroyi (Micaud, 1828)

    Raphitoma linearis (Montagu, 1803)
    Raphitoma pseudohystrix (Sykes, 1906)
    Raphitoma purpurea (Montagu, 1803)

Ordo HETEROSTROPHA P. Fischer, 1885

Familia OMALOGYRIDAE G.O. Sars, 1878

Genus *Omalogyra* Jeffreys, 1859
    Omalogyra simplex O.G. Costa, 1861

Familia CORNIROSTRIDAE Ponder, 1990

Genus *Tomura* Pilsbry et MacGinty, 1946
    Tomura depressa (Granata-Grillo, 1877)

Familia RISSOELLIDAE Gray, 1850

Genus *Rissoella* Gray, 1847
    *Rissoella inflata (*Monterosato, 1880)
    Rissoella opalina (Jeffreys, 1848)

Familia PYRAMIDELLIDAE Gray, 1840

Genus *Chrysallida* Carpenter, 1856
    Chrysallida emaciata (Brusina, 1866)
    Chrysallida excavata (Philippi, 1836)
    Chrysallida intermixta (Monterosato, 1884)
    Chrysallida interstincta (J. Adams, 1797)
    Chrysallida moolenbeeki Amati, 1987
    Chrysallida penchynati (Bucquoi, Dautzenberg et Dollfus, 1883)

Genus *Odostomella* Bucquoy, Dautzenberg et Dollfus, 1883
    Odostomella doliolum (Philippi, 1844)

Genus *Euparthenia* Thiele, 1931
    Euparthenia humboldti (Risso, 1826)

Genus *Eulimella* Forbes et M'Andrew,1846
    Eulimella acicula (Philippi, 1836)

Genus *Megastomia* Monterosato, 1884
    Megastomia conoidea (Brocchi, 1814)

Genus *Odostomia* Fleming, 1813
    Odostomia carrozai Van Aartsen, 1987
    Odostomia eulimoides Hanley, 1844
    Odostomia lukisii Jeffeys, 1859
    Odostomia scalaris Mac Gillivray, 1843

Odostomia turrita Hanley, 1844
Odostomia unidentata (Montagu,1803)

Genus *Ondina* De Folin, 1870
  Ondina vitrea (Brusina, 1866)

Genus *Parthenina* Bucquoy, Dautzenberg et
Dollfus, 1883
  Parthenina dollfusi Kobelt, 1903

Genus *Turbonilla* Risso, 1826
  Turbonilla pumila Seguenza G., 1876
  Turbonilla striatula (Linnaeus, 1758)

Familia AMATHINIDAE Ponder, 1987

Genus *Clathrella* Récluz, 1864
  Clathrella clathrata (Philippi, 1844)

Familia MURCHISONELLIDAE Casey, 1904

Genus *Ebala* Gray, 1847
  Ebala nitidissima (Montagu, 1803)

Ordo CEPHALAPSIDEA Fischer, 1883

Familia HAMINOEIDAE Pilsbry, 1895

Genus *Haminoea* Turton et Kingston in Carrington,
1830
  Haminoea hydatis (Linnaeus, 1758)

Genus *Weinkauffia* Monterosato, 1884
  Weinkauffia turgidula (Forbes, 1884)

Familia RETUSIDAE Thiele, 1925

Genus *Retusa* T. Brown, 1827
  Retusa mammillata (Philippi, 1836)
  Retusa truncatula (Bruguière, 1792)
  Retusa umbilicata (Montagu, 1803)

Ordo THECOSOMATA de Blainville, 1824

Familia CAVOLINIIDAE Gray, 1850

Genus *Cavolinia* Abildgaard, 1791
  Cavolinia inflexa (Lesueur, 1813)

Familia CLIIDAE Jeffreys, 1869

Genus *Clio* Linnaeus, 1767
  Clio pyramidata Linnaeus, 1767

Familia CRESEIDAE Rampal, 1973

Genus *Creseis* Rang, 1828
  Creseis clava (Rang, 1828)

Genus *Styliola* Gray, 1847
  Styliola subula (Quoy et Gaimard, 1827)

Ordo UMBRACULIDA Dall, 1899

Familia TYLODINIDAE Gray, 1847

Genus *Tylodina* Rafinesque, 1814
  Tylodina perversa (Gmelin, 1791)

Ordo PULMONATA Cuvier, 1817

Familia SIPHONARIIDAE Gray, 1827

Genus *Williamia* Monterosato, 1844
  Williamia gussonii (O.G. Costa, 1829)

Familia TRIMUSCULIDAE J.Q. Burch, 1945

Genus *Trimusculus* F.C. Schmidt, 1818
  Trimusculus mammilaris (Linnaeus, 1758)

Classis BIVALVIA Linnaeus, 1758
Ordo SOLEMYOIDA Dall, 1889

Familia NUCULIDAE Gray, 1824

Genus *Austronucula* Powell,1939
  Austronucula perminima (Monterosato, 1875)

Ordo ARCOIDA Stoliczka, 1871

Familia ARCIDAE Lamarck, 1809

Genus *Arca* Linnaeus, 1758
  Arca noae Linnaeus, 1758
  Arca tertragona Poli, 1795

Genus *Asperarca* Sacco, 1898
  Asperarca nodulosa (O.F. Müller,1776)
  Asperarca secreta La Perna, 1998

Genus *Barbatia* Gray, 1842
 Barbatia barbata (Linnaeus, 1758)

Familia NOETIIDAE Steward, 1930

Genus *Striarca* Conrad, 1862
 Striarca lactea (Linnaeus, 1758)

Ordo MYTILOIDA Férussac, 1822

Familia MYTILIDAE Rafinesque, 1815

Genus *Mytilus* Linnaeus, 1758
 Mytilus galloprovincialis Lamarck, 1819

Genus *Crenella* T.Brown, 1827
 Crenella arenaria Monterosato, 1875 ex H. Martin, ms.

Genus *Gregariella* Monterosato, 1884
 Gregariella semigranata (Reeve, 1858)

Genus *Musculus* Röding, 1798
 Musculus costulatus (Risso, 1826)
 Musculus discors (Linnaeus, 1767)

Genus *Lithophaga* Röding, 1798
 Lithophaga lithophaga (Linnaeus, 1758)

Genus *Modiolus* Lamarck, 1799
 Modiolus barbatus (Linnaeus, 1758)

Genus *Modiolula* Sacco, 1897
 Modiolula phaseolina (Philippi, 1844)

Genus *Rhomboidella* Monterosato, 1884
 Romboidella prideauxi (Leach, 1815)

Ordo PECTINOIDA Gray, 1854

Familia PECTINIDAE Rafinesque, 1815

Genus *Talochlamys* Iredale, 1935
 Talochlamys multistriata (Poli, 1795)

Genus *Flexopecten* Sacco, 1897
 Flexopecten flexuosus (Poli, 1795)
 Flexopecten hyalinus (Poli, 1795)

Familia PROPEAMUSSIIDAE Abbot, 1954

Genus *Cyclopecten* A.E.Verrill, 1897
 Cyclopecten brundisiensis Smriglio et Mariottini, 1990

Familia SPONDYLIDAE Gray, 1826

Genus *Spondylus* Linnaeus, 1758
 Spondylus gaederopus Linnaeus, 1758

Ordo LIMOIDA Moore, 1952

Familia LIMIDAE Rafinesque, 1815

Genus *Lima* Bruguière, 1797
 Lima lima (Linnaeus, 1758)

Genus *Limaria* Link, 1807
 Limaria hians (Gmelin, 1791)
 Limaria tuberculata (Olivi, 1792)

Genus *Limatula* S.V. Wood, 1839
 Limatula subauriculata Habe, 1958
 Limatula subovata (Monterosato, 1875)

Ordo LUCINOIDA Gray, 1854

Familia LUCINIDAE Fleming, 1828

Genus *Ctena* Mörch, 1860
 Ctena decussata (O.G. Costa, 1829)

Genus *Lucinella* Monterosato, 1884
 Lucinella divaricata (Linnaeus, 1758)

Ordo VENEROIDA Gray, 1854

Familia CHAMIDAE Lamarck, 1809

Genus *Chama* Linnaeus, 1758
 Chama gryphoides Linnaeus, 1758

Genus *Pseudochama* Odhner, 1917
 Pseudochama griphina (Lamarck, 1819)

Familia LASAEIDAE Gray, 1842

Genus *Lasaea* Brown, 1827
 Lasaea adansoni (Gmelin, 1791)

Familia NEOLEPTONIDAE Thiele, 1934

Genus *Neolepton* Monterosato, 1875
    Neolepton sulcatulum (Jeffreys, 1859)

Familia CARDIIDAE Lamarck, 1809

Genus *Parvicardium* Monterosato, 1884
    Parvicardium exiguum (Gmelin, 1791)
    Parvicardium scriptum (Bucquoy, Dautzenberg
et Dollfus, 1892)

Genus *Papillicardium* Sacco, 1899
    Papillicardium papillosum (Poli, 1791)

Familia TELLINIDAE Blainville, 1814

Genus *Moerella* (Linnaeus, 1758)
    Moerella donacina (Linnaeus, 1758)
    Moerella pygmaea (Lovén, 1846)

Familia TRAPEZIDAE Lamy, 1920

Genus *Coralliophaga* Blainville, 1824
    Coralliophaga lithophagella (Lamarck, 1819)

Familia VENERIDAE Rafinesque, 1815

Genus *Venus* Linnaeus, 1758
    Venus casina Linnaeus, 1758
    Venus verrucosa Linnaeus, 1758

Genus *Timoclea* T. Brown, 1827
    Timoclea ovata (Pennant, 1777)

Genus *Gouldia* C.B. Adams, 1847
    Gouldia minima (Montagu, 1803)

Genus *Irus* F.C. Schmidt, 1818
    Irus irus (Linnaeus, 1758)

Ordo CARDITOIDA Dall, 1889

Familia CARDITIDAE Férussac, 1822

Genus Cardita Bruguiére, 1792
    Cardita calyculata (Linnaeus, 1758)

Genus *Glans* Megerle von Mühlfeldt, 1811
    Glans trapezia (Linnaeus, 1767)

Genus *Centrocardita* Sacco, 1899
    Centrocardita aculeata (Poli, 1795)

Familia ASTARTIDAE d'Orbigny, 1844

Genus *Astarte* J.C. Sowerby, 1816
    Astarte fusca (Poli, 1791)

Ordo MYOIDA Stoliczka, 1870

Familia MYIDAE Lamarck, 1809

Genus *Sphenia* Turton, 1822
    Sphenia binghami Turton, 1822

Familia HIATELLIDAE Gray, 1824

Genus *Hiatella* Bosc, 1801
    Hiatella arctica (Linnaeus, 1767)
    Hiatella rugosa (Linnaeus, 1767)

Ordo ANOMALODESMATA Dall, 1889

Familia THRACIIDAE Stoliczka, 1870

Genus *Thracia* Blainville, 1824
    Thracia distorta (Montagu, 1803)
    Thracia villosiuscula (Mac Gillivray, 1827)

Familia LYONSIIDAE P. Fischer, 1887

Genus *Lyonsia* Turton, 1822
    Lyonsia norwegica (Gmelin, 1791)

Classis SCAPHOPODA Bronn, 1862
Ordo DENTALIIDAE da Costa, 1776

Familia GADILINIDAE Chistikov, 1975

Genus *Episiphon* Pilsbry et Sharp, 1897
    Episiphon filum (G.B. Sowerby II, 1860)

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The long journey of *Fusinus rostratus* (Olivi, 1792) (Gastropoda Fasciolariidae) from Portugal coasts to Venice Lagoon

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ABSTRACT   In the present paper the following morpha of *Fusinus rostratus* (Olivi, 1792) (Gastropoda Fasciolariidae) were investigated: Atlantic, Central and Southern Tyrrhenian Sea, Egadi Islands and the Sicilian Channel, Coasts of North Africa, the Central Adriatic Sea, Upper Adriatic Sea and the Venice Lagoon. Each of these morpha shows such morphological characteristics to be easily separated from the others. It is interesting to observe that the morphotype from the coast of Portugal is by far morphologically the closest to that from Northern Adriatic. A feature common to all the described morphotypes, is the presence of secondary cords, regularly spaced between the primary ones. The aim of this study is to split this species by geographical areas in order to facilitate further studies.

KEY WORDS   *Fusinus rostratus*; Fasciolariidae; Mediterranean Sea; morphotipi.

INTRODUCTION

The *Fusinus rostratus* (Olivi, 1792) (Gastropoda Fasciolariidae) is a species distributed all over the Mediterranean Sea.

It is more common in the Northern and Central Adriatic and in Tyrrhenian Sea. It is also reported for the Atlantic Coasts, Portugal (Hidalgo, 1917; Barash & Danin, 1992), the Canary Islands (Aradas & Benoit, 1870 Poppe & Goto, 1991; Barasch & Danin, 1992). There are also records from Morocco (Pasteur-Humbert, 1962; Barasch & Danin, 1988, 1992; Ardovini & Cossignani, 2004) and Mauritania (Lozet & Dejean-Arrecgros, 1977) but these latters should be investigated; rare in the Aegean Sea with records that require a careful study (personal observation). According to Mallard & Robin (2005), *F. rostratus* is endemic to the Mediterranean Sea.

F. rostratus is an eurybates species, found in a few centimeters of water in the Lagoon of Venice (Buzzurro & Russo, 2001; Russo, 2012) to a maximum of detected depth of 823 m (D'Amico, 1912).

This species is related to soft sediments (Vio & De Min, 1994, 1996), muddy (Monterosato, 1877), debris and muddy (Coen & Vatova, 1932), debris and muddy-sandy (Vatova, 1943), muddy-sandy (Vatova, 1940; Taviani, 1978).

F. rostratus also occurs in *Peyssonnelia polymorpha* facies and mäerl (Jacquotte, 1962; Ledoyer, 1969). It feeds on polychetes.

In the present paper the following morpha of *F. rostratus* were investigated: Atlantic, Central and Southern Tyrrhenian Sea, Egadi Islands and the Strait of Sicily, Coasts of North Africa, Central Adriatic Sea, Northern Adriatic Sea and the Venice Lagoon.

MATERIAL AND METHODS

Due to the considerable amount of available material, it was possible to select a typical range for all considered morpha. For the most part these are from residues of fishing. The following locations were selected: Atlantic: coasts of Portugal, Algarve from nets at 60 m; Central Thyrennian: Tuscan Archipelago from fishing vessels at 100/300 m; Southern Thyrennian, Pozzuoli from fishing vessels at 60 m; Strait of Sicily: Egadi Islands by fishing vessels at unknown depths; Coasts of North Africa: Algeria from creels at 60 m; Central Adriatic, Pescara from fishing vessels at 40–60 m; Northern Adriatic, Chioggia from nets for *Aequipecten opercularis* (Linnaeus, 1758) and *Pecten jacobaeus* (Linnaeus, 1758) at 25–30 m; Venice Lagoon, Pellestrina Island, harvested by hand during low tide.

SYSTEMATICS

Familia FASCIOLARIIDAE J.E. Gray, 1853
Subfamilia FUSININAE Wrigley, 1927
Genus *Fusinus* Rafinesque, 1815

Fusinus rostratus (Olivi, 1792)

Original description (Olivi, 1792): "*M. strombo di prima spezie di colore biondetto formato ad angoli, e tutto ricoperto di finissimi cordoncini, che gli girano pel traverso.* Gin. Adr. T. II. Pag. 8 tav. 7 fig. 56." (Fig.1).

A very brief description not easy to interpret. A more accurate description can be found in D'Ancona (1871): "*Conchiglia fusiforme allungata, acuminata all'apice e terminata alla base da un canale dritto, stretto, di poco più corto della spira. Questa consta di circa 9 giri convessi, carenati ad eccezione dei primi tre o quattro, divisi da una sutura molto profonda, i quali portano otto o nove coste longitudinali piuttosto grosse, rotondate, sporgenti, ristrette al loro principiare verso la sutura superiore e più larghe al loro terminare verso quella inferiore. Tutti gli anfratti sono divisi quasi nel mezzo in due porzioni pressoché uguali (la superiore sovente maggiore) da una carena rilevata, talora lamellosa e sfrangiata, producendo in tal caso in corrispondenza delle coste longitudinale delle punte molto ottuse e molto compresse dal basso all'alto, come apparisce dalla fig.*

9 (a, b) della Tav. 14. Numerosi sono i solchi ed i cordoncini traversi, ravvicinati fra loro, rilevati, rugosi e leggermente ondulati, i quali gradatamente diminuendo di numero e di grossezza giungono fino alla estremità del canale. Tali cordoncini sogliono essere un poco meno grossi nella porzione superiore dei giri, e nella inferiore si osserva ordinariamente che nel solco che divide due di loro vi ha un sottile filetto. Tutta la superficie della conchiglia è resa scabra da numerosissime linee di accrescimento sottilissime che rendono quasi granulosi i cordoncini trasversali. L'apertura è piuttosto piccola, ovale; il labbro alquanto spesso, è acuto nel margine ed internamente solcato; la lamina columellare perfettamente liscia nella maggior parte dei casi si rialza sul penultimo anfratto prolungandosi in questo modo anche lungo il canale. Il quale è mediocremente lungo, stretto, dritto ed aperto."

In *F. rostratus* the protoconch, always paucispiral, cannot be considered a diagnostic element (Buzzurro & Russo, 2007) as highly variable depending on the population. For further clarity here are illustrated the protoconchs of all the considered morpha with the exception of specimens from Egadi Islands due to lack of intact specimens (Figs. 2–8 and Table 1). The presence of secondary cords, regularly spaced between the primary ones, is an element of diagnostic character (Fig. 9). Normally the shells are 50–60 mm up to 87 mm high (Donnarumma, 1968), reaching 95 mm (Kaicher, 1978, unverified). It counts 76 synonymies.

Algeria	914	364
Chioggia	907	392
Civitavecchia	892	478
Pescara	928	385
Portugal	735	321
Pozzuoli	714	521
Strait of Messina	642	228
Venice Lagoon	664	385

Table 1. Sizes of protoconchs and nuclei (expressed in µm) of the described morphotypes.
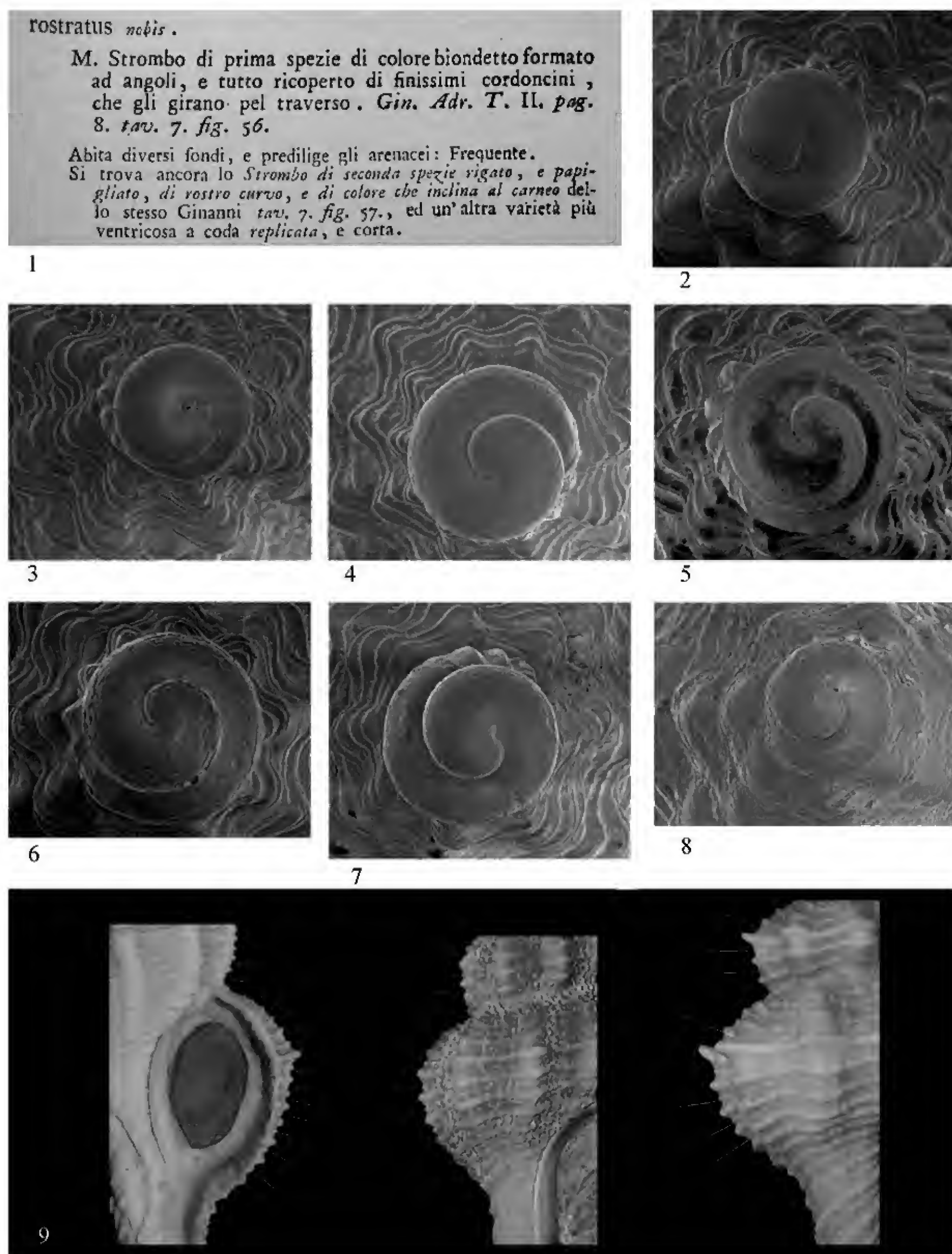
Figure 1. Original description of *Fusinus rostratus* Olivi, 1792. Figures 2–8. Protoconchs. Fig. 2: morphotype from Portugal. Fig. 3: morphotype from Southern Tyrrhenian. Fig. 4: morphotype from Central Tyrrhenian. Fig. 5: morphotype from North Africa. Fig. 6: morphotype from Central Adriatic. Fig. 7: morphotype from Northern Adriatic. Fig. 8: morphotype from Venice Lagoon. Figure 9. Secondary cords in *F. rostratus.*

Following is a summary of the main populations of the Mediterranean Sea.

COAST OF PORTUGAL (Figs. 10–12)

Medium sized
Shell rather thick and solid
Siphonal canal of medium length and slightly deviated
Teleoconch consisting of 7–7.5 whorls
Light brown or yellowish in color
Axial ribs not very prominent
Usually acarinate, sometimes the supramediane cord of the body whorl is slightly raised
Protoconch diameter 735 µm, nucleus 321 µm

CENTRAL TYRRHENIAN (Figs. 13–14)

Medium sized
Shell rather light
Siphonal canal long and straight
Teleoconch consisting of 7–7.5 whorls
Milk white, sometimes with pale yellow shades
Axial ribs not very prominent, sometimes barely hinted
Spiral cords rather thin and raised
Always acarinate
Protoconch diameter 892 µm, nucleus 478 µm

SOUTHERN TYRRHENIAN (Figs. 15–17)

Small and medium sized
Shell rather light
Siphonal canal long and straight
Teleoconch consisting of 7–7.5 whorls
Reddish brown
Axial ribs not very prominent
Spiral cords rather thin and raised
Always acarinate
Protoconch diameter 714 µm, nucleus 521 µm

EGADI AND STRAIT OF SICILY (Figs. 18–19)

Medium sized
Shell rather thick
Siphonal canal long and straight
Teleoconch consisting of 6–7 whorls
Whitish with pale yellow shades
Axial ribs little prominent, barely visible in the adapical area of the body whorl

Spiral cords irregular and of discontinuous thickness
Keel very raised
It was not possible to detect the protoconch for lack of intact specimens

NORTH COAST OF AFRICA (Figs. 20–22)

Medium sized
Shell rather thick and solid
Siphonal canal of medium length and slightly deviated to the left
Teleoconch consisting of 7 whorls
Pale yellow to light brown
Axial ribs normally rised
Spiral cords particularly evident and spaced
Generally has a rather evident keel
Presence of a rather evident columellar callus
Protoconch diameter 914 µm, nucleus 364 µm

CENTRAL ADRIATIC (Figs. 23–25)

Medium to large sized for the species
Shell thick and solid
Siphonal canal of medium length and often twisted
Teleoconch consisting of 7–7.5 whorls
Whitish in colour
Axial ribs not very raised
Spirals cords thin and of medium height
Whorls particularly inflated
Seldom a slight keel is present
Aperture particularly wide
Protoconch diameter 925 µm, nucleus 385 µm
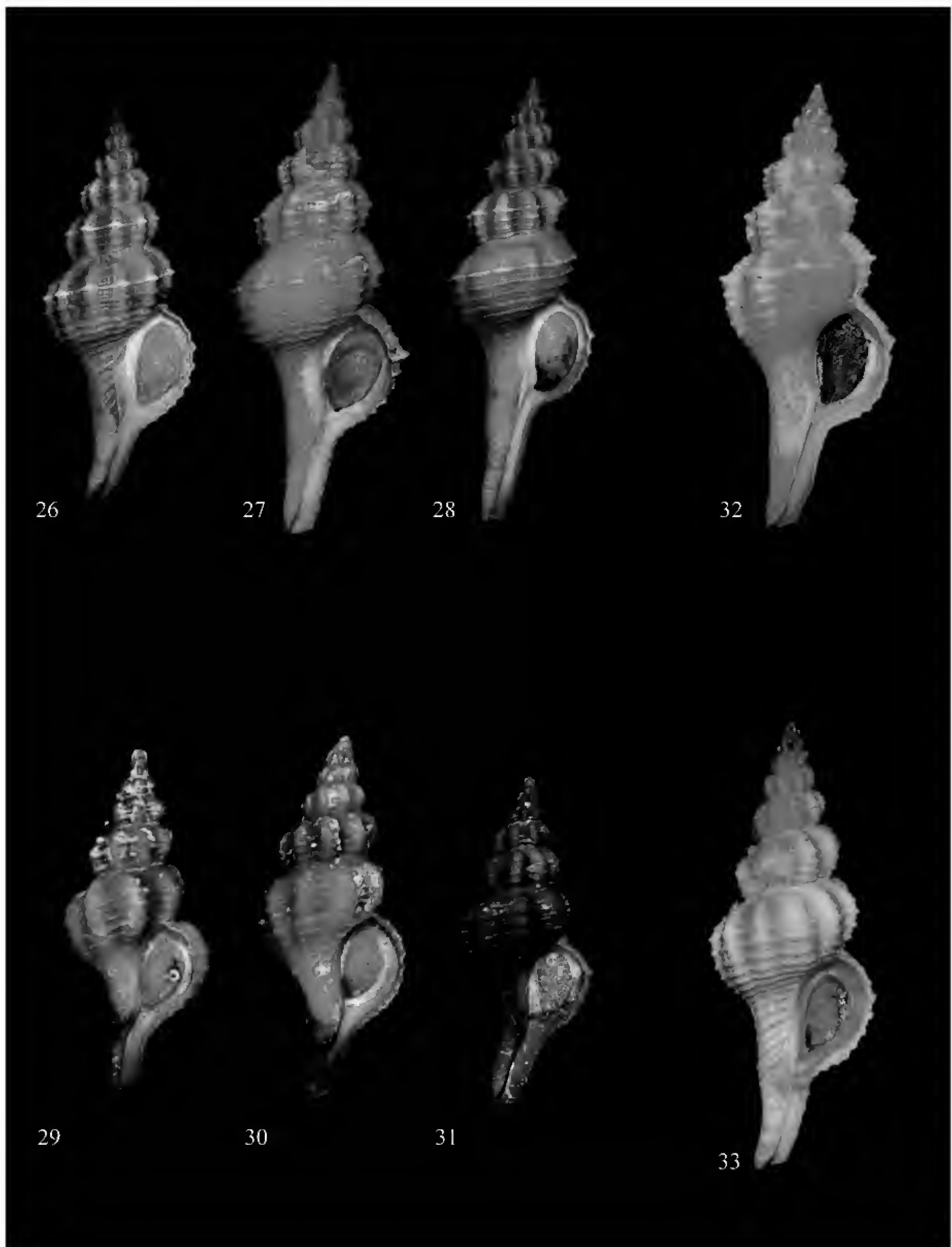
NORTHERN ADRIATIC (Figs. 26–28)

Medium sized
Shell rather thick
Siphonal canal of medium length and slightly deviated
Teleoconch consisting of 7–7.5 whorls
Deep reddish brown to pale yellow and straw-coloured
Axial ribs not very raised, sometimes lacking on the last whorl
Spirals cords thin and of medium height
Often acarinate, sometimes the supramediane cord of the last whorl slightly raised
Protoconch diameter 907 µm, nucleus 392 µm
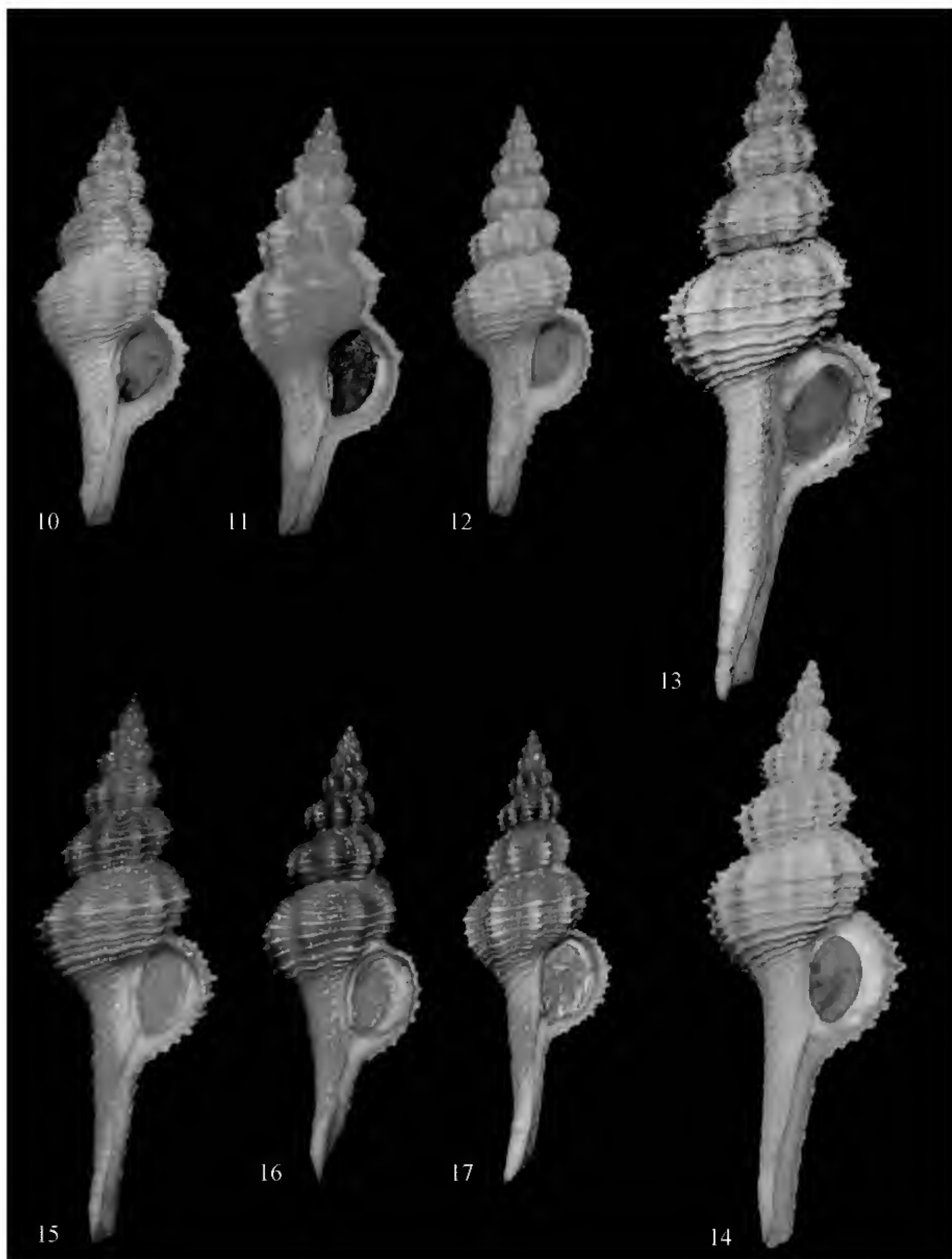
Figures 10–12. Morphotype from Coast of Portugal. Fig. 10. h: 39.3 mm, D: 14.5 mm. Fig. 11. h: 41.4 mm, D: 17.6 mm. Fig. 12. h: 35.3 mm, D: 12.2 mm. Figures 13, 14. Morphotype from Central Tyrrhenian. Fig. 13. h: 61.6 mm, D: 21.0 mm. Fig. 14. h: 47.5 mm, D: 20.4 mm. Figures 15–17. Morphotype from Southern Tyrrhenian. Fig. 15. h: 50.5 mm, D: 16.3 mm. Fig. 16. h: 36.4 mm, D: 12.7 mm. Fig. 17. h: 37.7 mm, D: 13.3 mm.
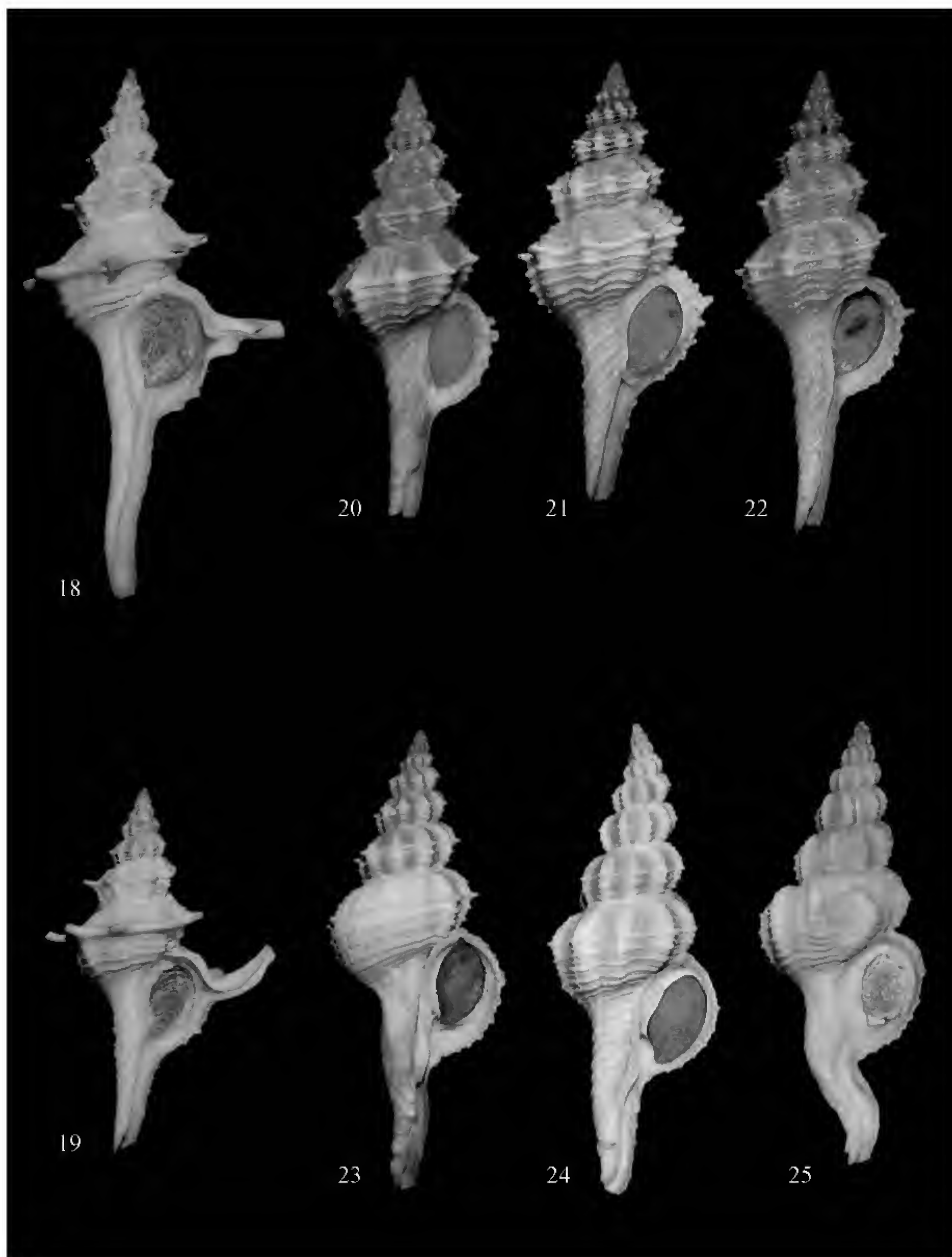
Figures 18, 19. Morphotype from Egadi and Strait of Sicily. Fig. 18. h: 46.0 mm, D: 24.7 mm. Fig. 19. h: 44.0 mm, D: 27.6 mm. Figures 20–22. Morphotype from North coast of Africa. Fig. 20. h: 40.5 mm, D: 14.6 mm. Fig. 21. h: 34.0 mm, D: 14.2 mm. Fig. 22. h: 40.6 mm, D: 15.4 mm. Figures 23–25. Morphotype from Central Adriatic. Fig. 23. h: 57.6 mm, D: 22.0 mm; Fig. 24. h: 59.0 mm, D: 22.2 mm; Fig. 25. h: 55.8 mm, D: 21.0 mm.

Figures 26–28. Morphotype from Northern Adriatic. Fig. 26. h: 40.0 mm, D: 15.2 mm; Fig. 27. h: 41.5 mm, D: 15.7 mm. Fig. 28. h: 61.0 mm, D: 21.4 mm. Figures 29–31. Morphotype from Venice Lagoon. Fig. 29. h: 27.4 mm, D: 12.0 mm; Fig. 30, h: 28.2 mm, D: 11.4 mm; Fig. 31. h: 25.2 mm, D: 11.0 mm. Figures 32–33. Comparison among the morphotype from Portugal Coasts (Fig. 32) and that from Northern Adriatic (Fig. 33).

VENICE LAGOON (Figs. 29–31)

    Small sized

    Shell rather thick and almost always eroded

    Siphonal canal short

    Teleoconch consisting of 5–6 whorls

    From dark brown to almost black in colour

    Axial ribs not very raised and often eroded

    Spirals cords thin and of little raised

    Always acarinate

    In some areas of the Venice Lagoon, during the low tide, it lives in absence of water

    Protoconch diameter 664 µm, nucleus 385 µm

RESULTS AND DISCUSSION

Each of these morpha shows such morphological characteristics to be easily separated from the others, therefore, despite being *F. rostratus* a polymorphic species, it is stable within the analyzed morpha.

It is interesting to observe that the morphotype from the coast of Portugal is by far morphologically the closest to that from the Northern Adriatic (Figs. 32, 33). This may not be surprising when one considers that the Northern Adriatic lagoon environments show, for concomitant geographical, climatic and environmental factors, sub-Atlantic rather than Mediterranean characteristics (Sacchi, 1977, 1983; Bianchi, 1983; Mizzan, 1999). Among the Northern Adriatic malacofauna we can include at least two other "cold" guests as *Littorina saxatilis* (Olivi, 1792) and *Calliostoma virescens* (Coen, 1933).

A feature common to all the described morphotypes, is the presence of secondary cords, regularly spaced between the primary ones. It is believed that this element is a diagnostic character (Merle, 2001, 2005; Crocetta et al., 2012; Russo, 2013) (Fig. 9).

It can therefore be said that the alternation of (primary cords, secondary cords) is a valuable character for the determination of *F. rostratus*, or rather, the presence of this sequence, excludes other species with the exception of *F. buzzurroi* Prkic et Russo,

Morphotipo	1		2		3		4		5		6		7		8			parametro
	h	d	h	d	h	d	h	d	h	d	h	d	h	d	h	d	somma	media h/d
Portogallo	44.4	17.7	41.0	16.0	42.5	17.0	29.6	12.0	31.0	11.7	30.3	11.8	29.4	11.6	39.4	15.3		
h/d	2.51		2.56		2.50		2.47		2.65		2.57		2.53		2.58		20.36	**2.55**
Medio Tirreno	61.4	21.2	60.0	19.4	60.0	19.6	57.0	20.0	57.0	20.0	53.0	20.0	53.0	19.0	57.0	17.2		
h/d	2.90		3.09		3.06		2.85		2.85		2.65		2.79		3.31		23.50	**2.94**
Basso Tirreno	53.0	27.6	50.3	16.6	36.4	12.0	37.6	13.3	36.3	12.4	41.3	13.8	33.4	12.8	28.0	10.7		
h/d	1.92		3.03		3.03		2.83		2.93		2.99		2.61		2.62		21.96	**2.74**
Nord Africa	40.6	15.8	40.3	14.0	34.0	14.0	32.0	12.8	34.0	12.5	40.0	14.0	39.0	15.0	34.5	13.0		
h/d	2.57		2.88		2.43		2.50		2.72		2.86		2.60		2.65		21.21	**2.65**
Medio Adriatico	57.8	23.0	57.8	21.6	54.0	20.0	53.2	19.0	42.7	18.3	55.0	21.0	44.5	18.0	44.7	19.0		
h/d	2.51		2.68		2.70		2.80		2.33		2.62		2.47		2.35		20.47	**2.56**
Alto Adriatico	43.6	18.4	46.2	16.8	40.0	15.0	46.0	17.8	37.4	13.0	45.0	18.0	48.0	18.0	49.0	19.0		
h/d	2.37		2.75		2.67		2.58		2.88		2.50		2.67		2.58		20.99	**2.62**
Laguna di Venezia	25.0	10.6	27.4	12.0	26.0	11.2	28.2	11.9	25.0	10.8	21.5	10.0	31.0	12.3	26.8	12.0		
h/d	2.36		2.28		2.32		2.37		2.31		2.15		2.52		2.23		18.55	**2.32**

Table 2. h/D ratio of the described morphotypes.

2008 but this latter is easily distinguishable. These observations were made on a large amount of specimens from the different localities.

To confute this thesis the observations were extended also to a number of tropical species of the genus *Fusinus*, not useful to list here, confirming that the presence of secondary cords is not occasional and cannot be attributed to the single specimen: some species possess them and others do not.

From the observation of several juveniles it can be seen that for a height of 8 mm there are not yet secondary cords for 3 whorls; for a height of 14 mm and 4 whorls they appear on the body whorl; in specimens with 5–5,5 whorls they appear also in the penultimate whorl and in the larger ones with 7 whorls the secondary cords are present from the third last whorl.

This preliminary study has not dealt with the problem of a possible specific division of the different morpha of *Fusinus rostratus*. The current state of the art considers them all belonging to the same species.

The aim of this study is to split this species by geographical areas in order to facilitate further studies.

ACKNOWLEDGEMENTS

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Phenotypic diversity of *Thuridilla hopei* (Vérany, 1853) (Gastropoda Heterobranchia Sacoglossa). A DNA-barcoding approach

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ABSTRACT

The sacoglossan *Thuridilla hopei* (Vérany, 1853) shows highly diverse chromatic patterns. Based on the morphological examination of specimens from different Mediterranean localities, we have observed that in spite of this great variability in colours of *T. hopei*, two major chromatic morphotypes are related to bathymetry. Specimens from deeper water exhibit blue darker and more uniform patterns than individuals from shallower water, which show a more variable, dashed and spotted arrangement of light blue, yellow, orange, white and black pigmentation. A molecular genetic analysis using the mitochondrial COI and 16S rDNA markers has confirmed that all these extremely different chromatic morphotypes belong to a single specific entity, i.e. *T. hopei*, a sacoglossan with a wide distribution, from Macaronesia in the Atlantic, to the easternmost Mediterranean Sea.

INTRODUCTION

The plakobranchid sacoglossan genus *Thuridilla* Bergh, 1872 is represented in the northeastern Atlantic and in the Mediterranean Sea by two species, *T. hopei* (Vérany, 1853) (Carmona et al., 2011; Malaquias et al., 2012) and the amphiatlantic *T. mazda* Ortea et Spinosa, 2000, recently recorded from the Azores (Malaquias et al., 2012). The brightly coloured *T. hopei* lives from the lower intertidal down to about 35 m depth, and generally is found crawling on hard substrate. It feeds suctorially on photophilous algae, in particular on *Derbesia tenuissima* (de Notaris) Crouan et Crouanand

Cladophora vagabunda (Linnaeus) van den Hoek (Marín & Ros, 2004; Händeler & Wägele, 2007; Händeler, 2011) and it retains functional algal chloroplasts from its food for few days (Marín & Ros, 1989, 2004). The aposematic chromatic pattern of this slug is related to the presence in its tissues of toxic compounds like the diterpenoids thuridillin A, B and C and nor-thuridillin (Gavagnin et al., 1993; De Rinaldis, 2012).

During the last decade, the high levels of intraspecific chromatic variation of *T. hopei* has been well documented in literature (Trainito, 2005; Händeler, 2011; Carmona et al., 2011 and references therein), as well as depicted in the Sea Slug

Forum (Australian Museum, Sydney, Available from http://www.seaslugforum.net/). It is worth of mentioning that the Macaronesian specimens of *T. hopei*, have long been ascribed to the Caribbean *T. picta* (Verril, 1901), due to a similar colour pattern (see Cervera et al., 2004; Malaquias et al., 2009), until Carmona et al. (2011) demonstrated by genetic data that they belong to *T. hopei*.

We have observed and documented the chromatic variability of *T. hopei* at different Mediterranean localities, particularly along the Italian coast. Interestingly, we observed that the distribution of different chromatic phenotypes is related to bathymetry, as previously reported by Cattaneo-Vietti (1990) and Händeler (2011). Specimens from deeper water exhibit dark blue and more uniform patterns ("bluish" form according to Händeler, 2011: 37) than individuals from shallower water, which show a more dashed and spotted arrangement of light blue, yellow, orange, white and black pigmentation ("rosy" form according to Händeler, 2011: 37). Different colour types have been usually considered as chromatic morphotypes of *T. hopei*, despite the consistent chromatic differences linked to their bathymetry (Carmona et al., 2011).

Therefore, we wanted to either confirm or deny the conspecificity of "bluish" and "rosy" forms by genetic data, being the significance of chromatic differences difficult to evaluate based on morphological data alone. In this study we applied a molecular analysis, using two mitochondrial markers, the barcode COI and the 16S rDNA, to the different colour morphotypes of *T. hopei*, to test the hypothesis that "bluish" and "rosy" specimens of these snails belong to the same species and confirm the lusitanic distribution of this sacoglossan sea slug.

MATERIAL AND METHODS

Collection data, vouchers and accession numbers are listed in Table 1. Italian specimens from several localities were collected by hand during SCUBA diving at different depth. Each specimen was photographed in situ and/or in aquarium, then fixed in ethanol.

A piece of tissue was dissected from the foot for DNA extraction, and the remaining animal was deposited at the Department of Biology and Biotechnologies "Charles Darwin" (La Sapienza Rome

University). DNA was extracted using a standard proteinase K phenol/chloroform method with ethanol precipitation, as reported in Oliverio & Mariottini (2001). A fragment of the mitochondrial 16S rDNA was amplified by PCR using the universal primers 16Sar-L and 16Sbr-H (Palumbi et al., 2001), while a fragment of the mitochondrial cytochrome oxidase I (COI) was amplified using the universal primers LCO1490 and HCO2198 (Folmer et al., 1994); for PCR conditions see Prkić et al. (2014). All amplicons were sequenced by Genechron Centre of Sequencing, ENEA (La Casaccia, Rome, Italy) or by European Division of Macrogen Inc. (Amsterdam, The Netherlands), using the same PCR primers.

Forward and reverse sequences were assembled and edited, and the resulting consensus sequences of each specimen were readily aligned by hand. BLAST search was always conducted for each sequence. Published sequences (COI and 16S) of *Thuridilla* were downloaded from theGenBank. Although the definition of a phylogenetic hypothesis for the genus *Thuridilla* was not within the aims of this paper, nevertheless, phylogenetic relationships among the *Thuridilla* sequences were inferred to have a phylogenetic framework for the estimation of the genetic distances: we used neighbour-joining (NJ) and maximum likelihood (ML) (both bootstrapped over 1000 replicates), by the software MEGA 5.0 (Tamura et al., 2011) and Bayesian Inference (BI) by the software MrBayes (with 5^*10^6 generations, and 25% burnin) by MrBayes 3.2.2 (Ronquist et al., 2012). Sequences of the Atlantic *Elysia timida* Risso, 1818, retrieved from the GenBank, were used as outgroup. Nodes in the phylogenetic trees were considered 'highly' supported with Bayesian posterior values ≥96% and bootstrap values ≥80%; nodes with Bayesian posterior values of 90–95% and bootstrap values of 70–79% were considered 'moderately' supported (lower support values were considered not significant).

Genetic divergence among the barcode COI sequences was observed (p distance) and estimated using the Kimura-2-parameters nucleotide substitution model (K2p distance).

RESULTS AND DISCUSSION

Animals were observed and sampled at seven localities of the Tyrrhenian Sea (Table 1).

Species	Voucher ID	Locality	COI	16S	References
Elysia timida	MNCN 15.05/53680	Menorca, Spain (MED)	HQ616847	--------------	Carmona et al., 2011
Elysia timida	MNCN 15.05/53680	Menorca, Spain (MED)	--------------	HQ616818	Carmona et al., 2011
Thuridilla albopustulosa	ZSM:20033615	NW-Sulawesi, Indonesia	--------------	EU140889	Händeler & Wägele, 2007
Thuridilla bayeri	--------------	--------------	DQ471279	DQ480208	Bass, 2006
Thuridilla bayeri	--------------	--------------	--------------	DQ480206	Bass, 2006
Thuridilla bayeri	--------------	--------------	--------------	DQ480207	Bass, 2006
Thuridilla bayeri	--------------	--------------	--------------	DQ480207	Bass, 2006
Thuridilla bayeri	ZSM:20033612	NW-Sulawesi, Indonesia	--------------	EU140886	Händeler & Wägele, 2007
Thuridilla carlsoni	--------------	Lizard Island, Australia	HM187640	--------------	Wägele et al., 2010
Thuridilla carlsoni	--------------	Lizard Island, Australia	--------------	EU140877	Händeler & Wägele, 2007
Thuridilla carlsoni	--------------	Lizard Island, Australia	--------------	EU140878	Händeler & Wägele, 2007
Thuridilla carlsoni	--------------	--------------	--------------	DQ480214	Bass, 2006
Thuridilla gracilis	--------------	Lizard Island, Australia	HM187641	--------------	Wägele et al., 2010
Thuridilla gracilis	--------------	Hamahiga, Okinawa, Japan	AB758972	--------------	Takano et al., 2013
Thuridilla gracilis	--------------	Lizard Island, Australia	--------------	EU140884	Händeler & Wägele, 2007
Thuridilla gracilis	--------------	Lizard Island, Australia	--------------	EU140885	Händeler & Wägele, 2007
Thuridilla gracilis	--------------	Lizard Island, Australia	--------------	EU140883	Händeler & Wägele, 2007
Thuridilla gracilis	--------------	Hamahiga, Okinawa, Japan	--------------	AB759041	Takano et al., 2013
Thuridilla hoffae	ZSM:20060224	Samoa	--------------	EU140880	Händeler & Wägele, 2007
Thuridilla hoffae	--------------	--------------	--------------	DQ480213	Bass, 2006
Thuridilla hopei	--------------	Elba Is., Italy (MED)	--------------	EU140881	Händeler & Wägele, 2007
Thuridilla hopei	CASIZ 184307	France (MED)	HQ616854	HQ616825	Carmona et al., 2011

Table 1. Voucher ID, collection localities and sequence accession numbers of *Thuridilla* and *Elysia* specimens. MED: Mediterranean; EA: Eastern Atlantic; WA: Western Atlantic (continued).

Species	Voucher ID	Locality	COI	16S	References
Thuridilla hopei	MNCN 15.05/53682	Menorca, Spain (MED)	HQ616849	HQ616820	Carmona et al., 2011
Thuridilla hopei	--------------	Mataro, Baretta del Abre, Barcelona, Spain (MED)	--------------	EU140882	Händeler & Wägele, 2007
Thuridilla hopei	MNCN/ADN 17015	Western Andalucia, Spain (EA)	HQ616855	HQ616826	Carmona et al., 2011
Thuridilla hopei	ZMBN 81680	Azores, Portugal (EA)	HQ616850	HQ616821	Carmona et al., 2011
Thuridilla hopei	ZMBN 81680	Azores, Portugal (EA)	HQ658123	--------------	Carmona et al., 2011
Thuridilla hopei	MNCN 15.05/53685	Madeira, Portugal (EA)	HQ616853	HQ616824	Carmona et al., 2011
Thuridilla hopei	--------------	Blanes, Cala St. Francesc, Spain (MED)	GQ996678	--------------	Händeler et al., 2009
Thuridilla hopei	--------------	Giglio Is., Italy (MED)	KC573743	--------------	Krug et al., 2013
Thuridilla hopei	--------------	Mataro, Baretta del Abre, Barcellona,Spain (MED)	GQ996677	--------------	Händeler et al., 2009
Thuridilla hopei	--------------	----------------------------	AF249810	--------------	Wollscheid-Lengeling et al., 2001
Thuridilla hopei	BAU1651.1	Giglio Is., Italy, 42°22'27"N 10°52'47"E, 30 m depth (MED)	KJ397547	KJ363910	Present study
Thuridilla hopei	BAU1651.2	Giglio Is., Italy, 42°22'27"N 10°52'47"E, 30 m depth (MED)	KJ397548	KJ363911	Present study
Thuridilla hopei	BAU1652	Le Formiche rocks, Italy, 42°34'28"N 10°52'58"E, 30 m depth (MED)	KJ397549	KJ363912	Present study
Thuridilla hopei	BAU1653.1	Sant'Agostino, Italy, 42°08'45"N 11°43'48"E, 25 m depth (MED)	KJ397550	KJ363913	Present study
Thuridilla hopei	BAU1653.2	Sant'Agostino, Italy, 42°08'45" N 11°43'48"E, 25 m depth (MED)	KJ397551	KJ363914	Present study
Thuridilla hopei	BAU1654	Giannutri Is., Italy, 42°15'07"N 11°07'04"E, 20 m depth (MED)	--------------	KJ363915	Present study
Thuridilla hopei	BAU1655.1	Ponza Is., Italy, 40°52'52"N 12°58'02"E, 25 m depth (MED)	--------------	KJ363916	Present study
Thuridilla hopei	BAU1655.2	Ponza Is., Italy, 40°52'52"N 12°58'02"E, 25 m depth (MED)	KJ397552	--------------	Present study
Thuridilla hopei	BAU1656	Cape Circeo, Italy, 41°13'31" N 13°03'02"E, 14 m depth (MED)	--------------	KJ363917	Present study
Thuridilla hopei	BAU1657.1	San Vito Lo Capo, Sicily, 38°10'02"N 12°46'11"E, 10 m depth (MED)	KJ397553	KJ363918	Present study

Table 1. Voucher ID, collection localities and sequence accession numbers of *Thuridilla* and *Elysia* specimens. MED: Mediterranean; EA: Eastern Atlantic; WA: Western Atlantic (continued).

Species	Voucher ID	Locality	COI	16S	References
Thuridilla hopei	BAU1657.1	San Vito Lo Capo, Sicily, 38°10'02"N 12°46'11"E, 10 m depth (MED)	KJ397553	KJ363918	Present study
Thuridilla hopei	BAU1657.2	San Vito Lo Capo, Sicily, 38°10'02"N12°46'11"E, 10 m depth (MED)	KJ397554	KJ363919	Present study
Thuridilla kathae	--------------	Lizard Island, Australia	--------------	EU140879	Händeler & Wägele, 2007
Thuridilla lineolata	--------------	Sulawesi, Indonesia	--------------	EU140887	Händeler & Wägele, 2007
Thuridilla livida	--------------	Merizo Clay's backyard, Guam	HM187636	--------------	Wägele et al., 2010
Thuridilla livida	--------------	Bile Bay, Guam	--------------	HM187607	Wägele et al., 2010
Thuridilla livida	--------------	----------------------------	--------------	DQ480211	Bass, 2006
Thuridilla mazda	UNAM 3027	Mexico	--------------	HQ616836	Carmona et al., 2011
Thuridilla neona	--------------	Lord Howe Is., Australia	KC573747		Krug et al., 2013
Thuridilla neona	--------------	----------------------------	--------------	DQ480209	Bass, 2006
Thuridilla picta	ZMBN 83023	Bermuda (WA)	HQ616851	HQ616822	Carmona et al., 2011
Thuridilla picta	ZMBN 83023	Bermuda (WA)	HQ658125	--------------	Carmona et al., 2011
Thuridilla picta	MNCN 15.05/53683	Colombia (WA)	HQ616861	HQ616832	Carmona et al., 2011
Thuridilla picta	MNCN 15.05/54991	Colombia (WA)	HQ616862	HQ616833	Carmona et al., 2011
Thuridilla picta	MNCN/ADN 17016	Cuba (WA)	HQ616852	HQ616823	Carmona et al., 2011
Thuridilla ratna	--------------	----------------------------	--------------	AF249256	Wollscheid-Lengeling et al., 2001
Thuridilla splendens	--------------	Kouri, Okinawa, Japan	AB758973	--------------	Takano et al., 2013
Thuridilla splendens	--------------	Kouri, Okinawa, Japan	--------------	AB759042	Takano et al., 2013
Thuridilla undula	--------------	----------------------------	--------------	DQ480210	Bass, 2006
Thuridilla vatae	--------------	Vaisala lagoon, Savaii Island, Samoa	HM187637	--------------	Wägele et al., 2010
Thuridilla vatae	ZSM:20060088	Samoa	--------------	EU140888	Händeler & Wägele, 2007
Thuridilla vatae	--------------	----------------------------	--------------	DQ480212	Bass, 2006

Table 1. Voucher ID, collection localities and sequence accession numbers of *Thuridilla* and *Elysia* specimens. MED: Mediterranean; EA: Eastern Atlantic; WA: Western Atlantic.
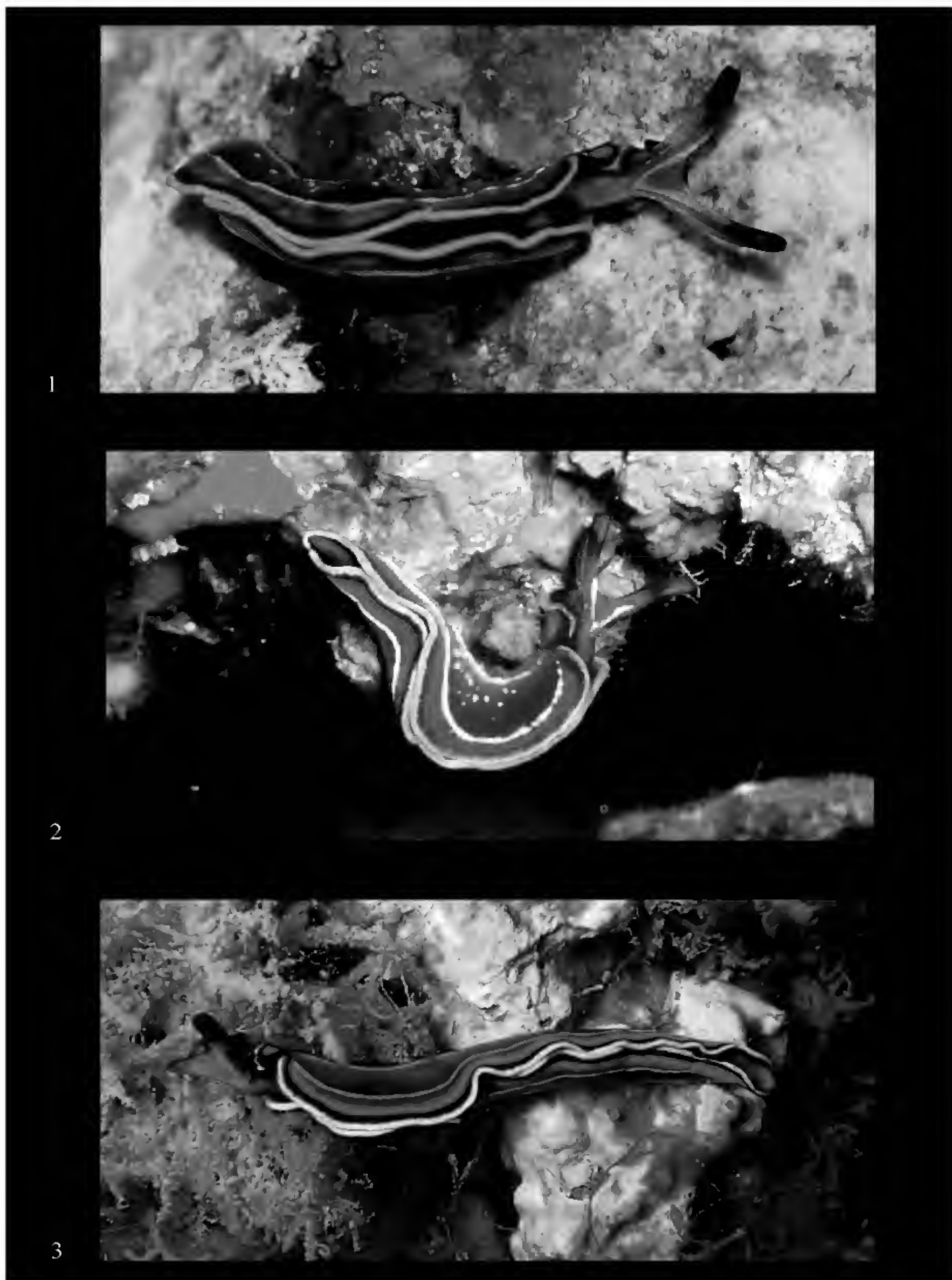
Figure 1. *Thuridilla hopei* "bluish" morphotype. Giannutri Is., Tuscany Archipelago, 42°15'07''N 11°07'04''E, Italy, 20 m depth. Figure 2. *T. hopei* "bluish" morphotype. St. Agostino, Latium coast, 42°08'45''N 11°43'48''E, Italy, 25 m depth. Figure 3. *T. hopei* "bluish" morphotype. Ponza is., Latium coast, 40°52'52''N 12°58'02''E, Italy, 25 m depth.
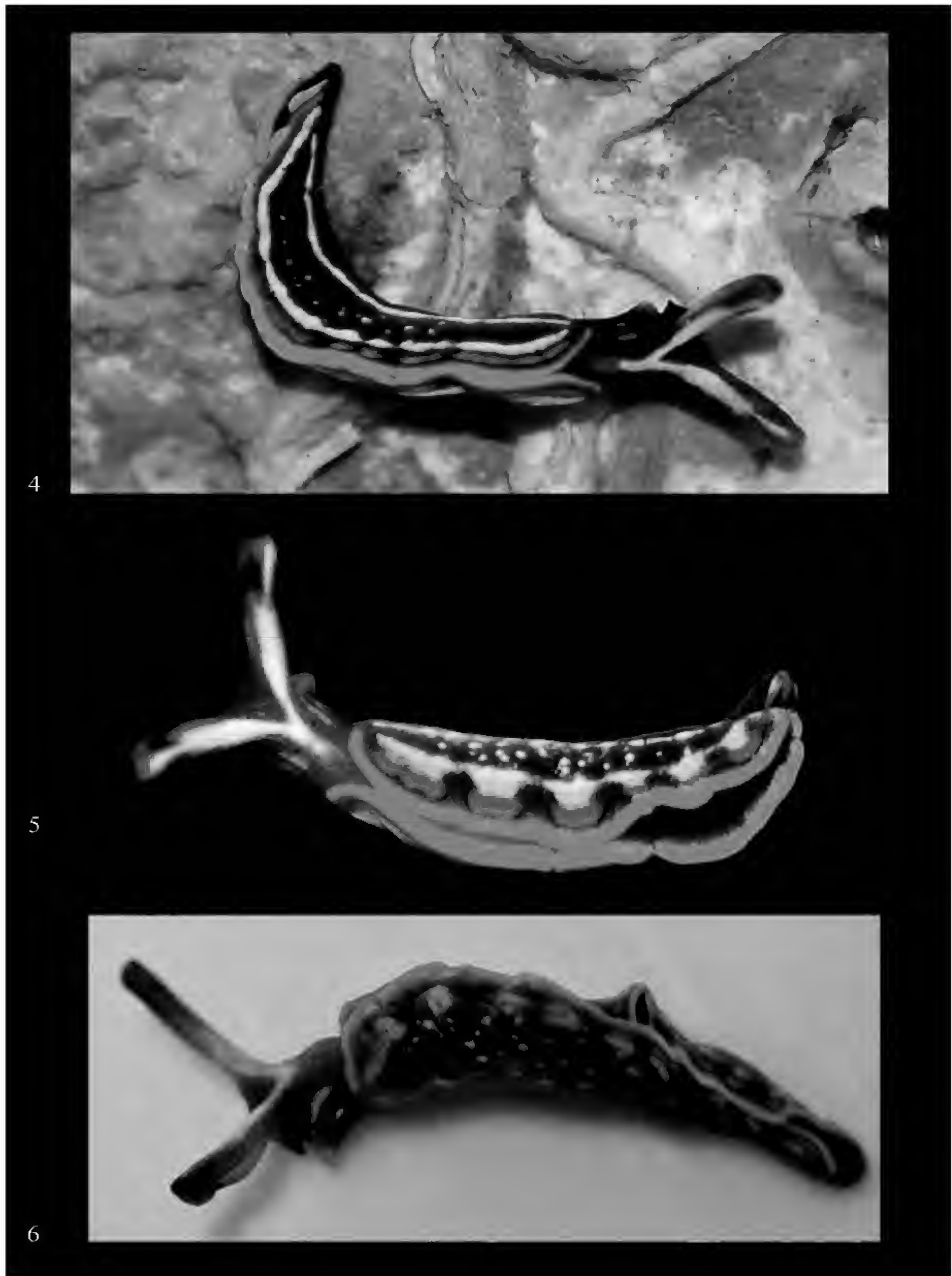
Figure 4. *Thuridilla hopei* "rosy" morphotype. Zannone Is., Latium coast, 40°57'19"N 13°03'19"E, Italy, 2 m depth. Figure 5. *T. hopei* "rosy" morphotype. San Vito Lo Capo, Sicily coast, 38°10'02"N 12°46'11"E, Italy, 10 m depth. Figure 6. *T. hopei* intermediate morphotype. St. Agostino, Latium coast, 42°08'45"N 11°43'48"E, Italy, 25 m depth.

According to the body colour, almost all specimens could be split into two main colour forms, the "bluish" (Figs. 1–3) and "rosy" (Figs. 4, 5) morphotypes. According to our data and other sources (see Table 2), slugs could be referred to: 1) the "bluish" form, showing a dark blue colour on the upper part of the rhinophores and living in deeper water (usually deeper than -25 m); 2) the "rosy" form, showing a wider white coloration of the rhinophores, including the upper portion, is a shallower water inhabitant (max depth recorded 15 m). Interestingly, the few specimens showing a colour pattern that was not easy to assign unambiguously (an example is depicted in Fig. 6), were collected at intermediate depths, from -20 to -25 m (Table 2; Fig. 7).

The phylogenetic analysis based on the partial sequences of COI and 16S mithocondrial genes, yielded similar trees (Figs. 8, 9). Since this work was not aimed to the definition of a molecular phylogenetic hypothesis for the entire genus *Thuridilla*, we will not discuss the phylogenetic details of the trees. We just notice that according to the relationships among the sequences of specimens of the complex of *T. bayeri* (Marcus, 1965), including also the nominal taxa *T. gracilis* (Risbec, 1928), *T. ratna* (Marcus, 1965), *T. splendens* (Baba, 1949), this group is worthy of a genetic approach to clarify the status of the various taxa. The sequences ascribed to *T. hopei* and *T. picta* (Verrill, 1901) were more closely related to *T. neona* Gosliner, 1995 than to any other species of the genus (support range: 95–98%), similarly to what found by Gosliner et al. (1995) based on an anatomical dataset. The difference in our trees was that *T. hopei* and *T. picta* formed two reciprocally monophyletic clades more closely related each other (98–99%) than to *T. neona*. In all phylogenetic analyses (Figs. 8, 9) the specimens of *T. picta* from the Caribbean formed a highly supported clade (98-99%). All specimens from the eastern Atlantic also formed a highly supported clade (98–100%), corresponding to *T. hopei* as conceived in Carmona et al. (2011).
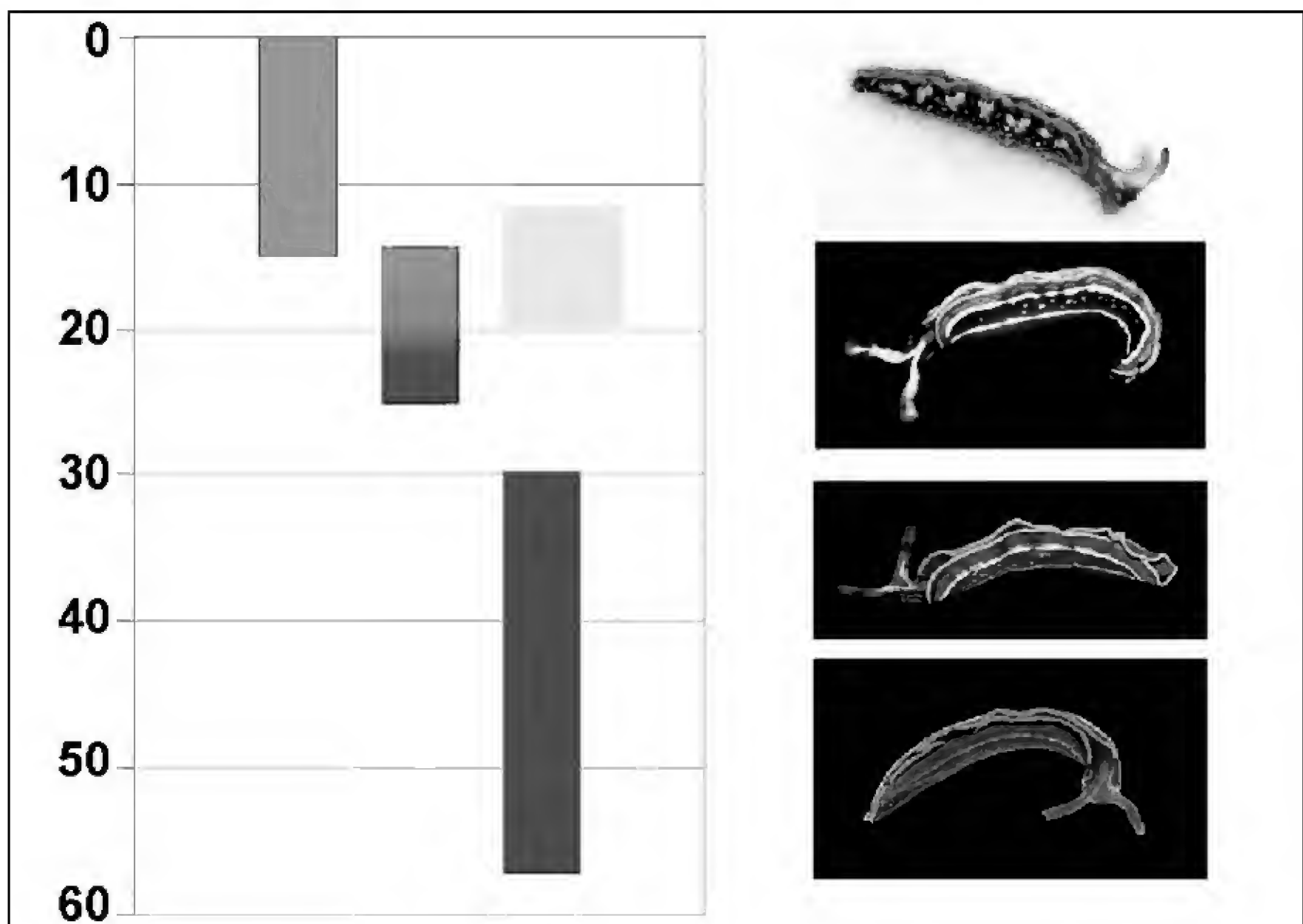
Figure 7. Depth ranges in meters of the 'rosy', 'bluish' and intermediate morphotypes, summarized from the data of Table 2.

T. hopei morphotypes	N° Specimens	Mediterranean records	Depth (meter)
Bluish	4	Le Formiche rocks, Italy, 42°34'28''N 10°52'58''E	30
	20	Giglio Is., Italy, 42°22'27''N 10°52'47''E	35
	10	Giannutri Is., Italy, 42°15'07''N 11°07'04''E	30
	15	St. Agostino, Italy, 42°08'45''N 11°43'48''E	25-30
	35	MPA "Secche di Tor Paterno", Italy, 41°36'00''N 12°19'00''E	25-35
	7	Ponza Is., Italy, 40°52'52''N 12°58'02''E	25-30
	1	Balun Is., Croatia (http://www.seaslugforum.net/message/1934)	57
	1	Area Marina Protetta "Secche di Tor Paterno", Italy, 41°36'00''N 12°19'00''E (Alberto Altomare, personal communication)	20-25
Intermediate	1	Giannutri Is., Italy, 42°15'07''N 11°07'04''E	20
	2	St. Agostino, Italy, 42°08'45''N 11°43'48''E	25
	1	Cap d'Antibes, France (http://www.seaslugforum.net/message/21023)	20
	1	Dive site "l'Ocell", Cerbere, France (http://www.seaslugforum.net/message/7551)	14
Rosy	13	"Secchitelle" Torvajanica, Italy, 41°34'15''N 12°19'09''E	10-14
	2	Torre Astura, Italy, 41°24'31''N 12°45'54''E	0.5
	1	off Cape Circeo, Italy, 41°13'31'' N 13°03'02''E	15
	1	Zannone Is., Italy, 40°57'19''N 13°03'19''E	2
	2	Santa Caterina, Italy, 40°08'23''N 17°59'12''E	2
	2	San Vito Lo Capo, Sicily, 38°10'02''N 11°46'11''E	10
	2	"La digue", Port-Leucate, France (http://www.seaslugforum.net/message/14769)	2
	1	Villafranche-sur-mer, France, (http://www.seaslugforum.net/message/22520)	5
	1	"Pierre qui tramole", Cap Croisette, France, (http://www.seaslugforum.net/message/7304)	15
	1	Kounoupeli beach, Ileia, Greece (http://www.seaslugforum.net/message/15307)	0.3
	1	Bodrum, Turkey (http://www.seaslugforum.net/message/17707)	15
	1	Michmort beach, Israel (http://www.seaslugforum.net/message/20048)	2
	24	Split, Croatia (Jakov Prkić, personal communication)	0-1
	20	Murter Island - loc. Kosirina, Croatia (Alen Petani, personal communication)	0-1
	7	Turanj, Croatia (Alen Petani, personal communication)	0-1
	> 300	Biograd - loc. Bošana, Croatia (Alen Petani, personal communication)	0-2
	5	Zadar - loc. Karma, Croatia (Alen Petani, personal communication)	0.5-2
	> 100	Zaton - loc. Bilotinjak, Croatia (Alen Petani, personal communication)	0-2
	5	Vrsi, Croatia (Alen Petani, personal communication)	0-1
	10	Nin - loc. Sabunike, Croatia (Alen Petani, personal communication)	0.5-1
	5	Vir Island - loc. Pedinka, Croatia (Alen Petani, personal communication)	1-2
	1	Dive site "Yellow Wall", Capoliveri, Elba Is., Italy (http://www.seaslugforum.net/message/1934)	11
	1	Capo Figari, Sardinia, (Egidio Trainito, personal communication)	15
	1	Divesite "Blue Grotto", Malta (http://www.seaslugforum.net/message/1934)	6
	1	"Secchitelle", Torvajanica, Italy (Alberto Altomare, personal communication)	10-15
	1	Brindisi, Italy (Vincenzo Marra, personal communication)	5-15

Table 2. Mediterranean Records of *Thuridilla hopei* assigned to bluish-rosy or intermediate morphotypes, with their locality and bathymetry. Original records by the authors, personal communications or retrieved from the Internet.
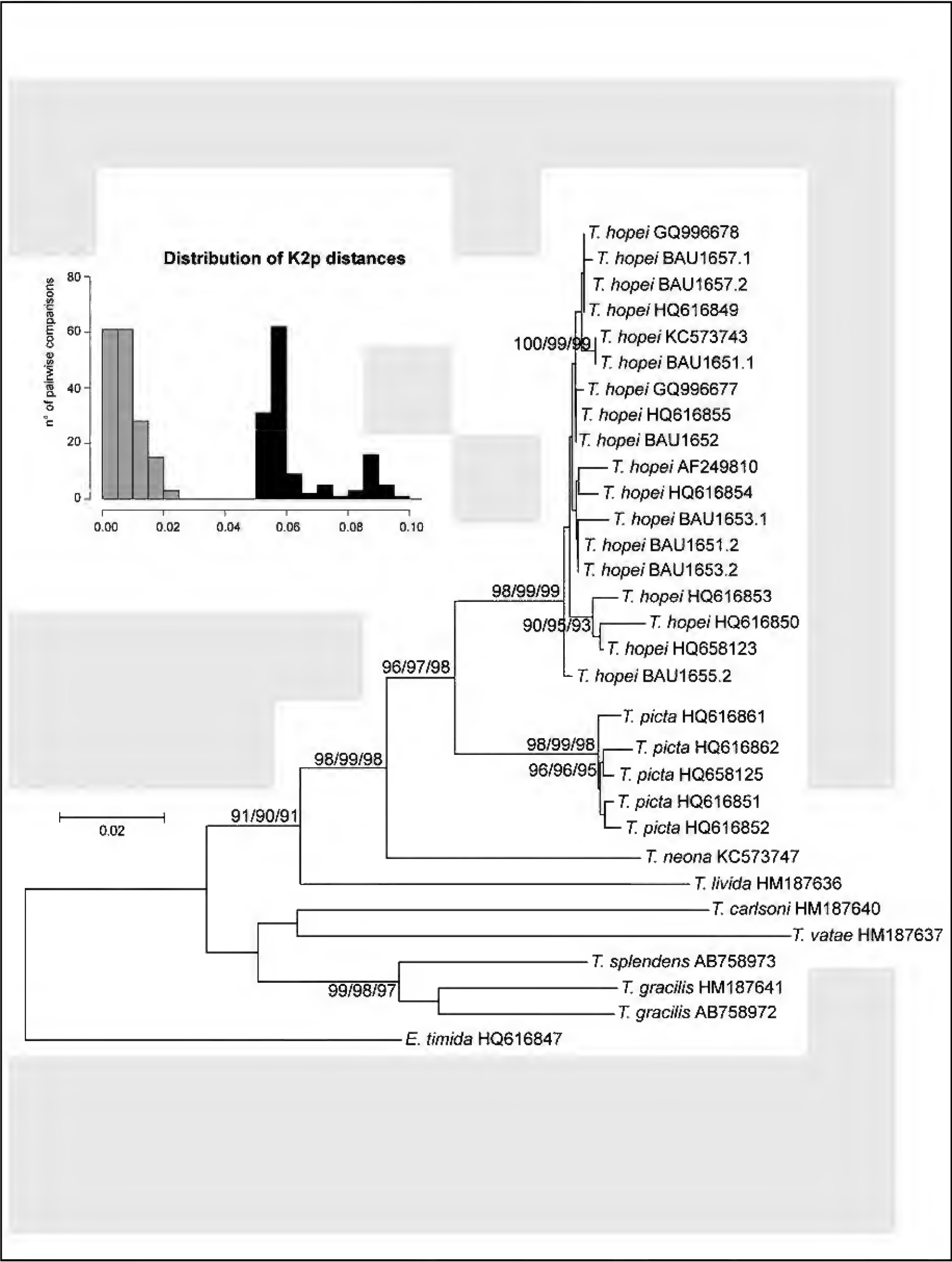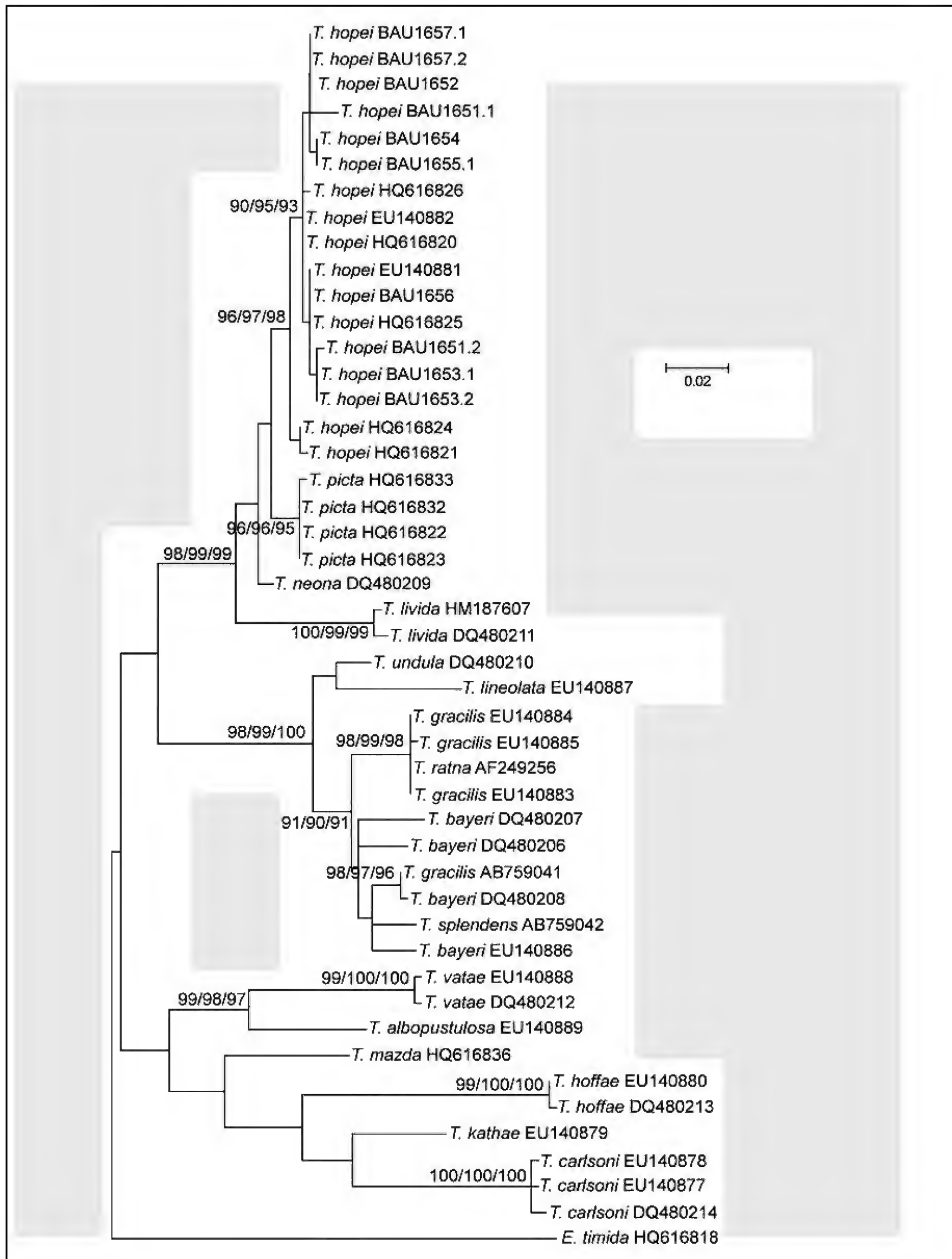
Figure 8. Maximum Likelihood tree based on the COI dataset (K2p model of evolution). Numbers at nodes are bootstrap on NJ and ML analyses (1000 replicates) and Bayesian posterior support ($5^{*}10^{6}$ generations and 25% burnin). Only moderately or highly supported nodes are annotated. Scale is calibrated ML distance. The histogram shows the distribution of the pairwise estimated genetic distances (K2p) in intraspecific (left, light grey) and interspecific (right, dark grey) comparisons.

Figure 9. Maximum Likelihood tree based on the 16S dataset (K2p model of evolution). Numbers at nodes are bootstrap on NJ and ML analyses (1000 replicates) and Bayesian posterior support ($5*10^6$ generations and 25% burnin). Only moderately or highly supported nodes are annotated. Scale is calibrated ML distance.

Figure 10. *Thuridilla hopei* "bluish" morphotype and *Felimare tricolor*. St. Agostino, Latium coast, 42°08'45''N 11°43'48''E, Italy, 35 m depth. Figure 11. *T. hopei* "bluish" morphotype and *Felimare fontandraui*. Giglio Is., Tuscany Archipelago, 42°22'27''N 10°52'47''E, Italy, 30 m depth.

The interspecific K2p genetic distances estimated on the COI sequence alignment (Fig. 8; distance matrices available on request from the authors), excluding the comparisons with the outgtroup, ranged from 5.1% to 20.8% (mean 11.6%). With the exception of the two specimens ascribed to *T. gracilis* (from a complex in need of revision, and with a distance of 6.8%), the K2p distances (COI) ranged from 0.5% to 0.9% (mean 0.7%) in the *T. picta* clade, and from 0% to 2.2% (mean 0.8%) in the *T. hopei* clade.

The largest distance values in the *T. hopei* clade were observed between the Macaronesian and the other eastern Atlantic and Mediterranean specimens (0.8%–2.2%). This is perfectly fitting a pattern with only two species involved in this clade, *T. picta* in the western and *T. hopei* in the eastern Atlantic, respectively, as previously proposed by Carmona et al. (2011).

Furthermore, our results do not support any taxonomic split of the "bluish" and "rosy" chromatic forms, which fall within the genetic variation of *T. hopei*. Interestingly, the "bluish" morphotype was often recorded at several Tyrrhenian localities (Figs. 10,11), in the same spots where also species of the family Chromodorididae of the blue chromatic group, such as *Felimare tricolor* (Cantraine, 1835) and *F. fontandraui* (Pruvot-Fol, 1951) were observed. Müllerian mimicry complexes have been described, involving similarly coloured toxic sea slugs, but sometimes including also polyclads (Gosliner, 2001: 166, fig. 1). In *T. hopei* the intraspecific variability of colour patterns, with somehow discrete morphotypes living at different depths, may be partly driven by mimicry coevolution.

The deeper water "bluish" morphotype observed in strict syntopy with the "blue" *Felimare* spp., might be a new Müllerian mimicry complex for the Mediterranean, where the sympatric species may have evolved the shared bright body colours and patterns convergently in the deeper waters (Gosliner, 2001). Conversely, no evidence has been so far collected for a similar mimicry complex involving the "rosy" morphotype in shallow waters. It is worth mentioning that the shallower specimens display a higher variability.

The Macaronesian specimens of *T. hopei*, could represent a third colour morphotype, since their colour pattern albeit similar to the "rosy" morphotype, yet shows a reduction of the dashed light-blue spots at the edge of the parapodia, a larger black portion without the basal white line, the terminal portion of rhinophores with a coloured band consisting of light blue, black and orange rings. This "ringed-rhinophore" chromatism, which has been so far documented in a single Mediterranean case, from Israel (Table 2, http://www.seaslugforum.net/message/20048), may either represent a third discrete colour morphotype or fall within the high variability of the shallow water *T. hopei*.

Future studies will focus on the selective factors acting at different depths, to maintain these two colour forms in the Mediterranean Sea.

ACKNOWLEDGEMENTS

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The molluscs found after the nourishment of the littoral of Terracina (Latium, Italy)

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ABSTRACT   In the present paper molluscs found after the beach nourishment carried out in 2006 on the coast of Terracina are reported. Altogether were identified 144 taxa, of which 105 Gastropoda, 37 Bivalvia and 2 Scaphopoda.

KEY WORDS   Mollusca; beach nourishment; Terracina; Italy; Mediterranean Sea.

INTRODUCTION

In the years 1950–60 the uncontrolled anthropic alteration carried out on the sandy coasts had as a consequence the modification of currents and tides, thus increasing the beach erosion. The first methods of consolidation of coasts were carried out in the absence of standards and draft rules, thus causing many environmental and aesthetic problems interfering with the dynamics of the coastline. This situation has made it necessary to study and fund several methods based on scientific and technical assessments. The purpose of beach nourishment is to rebuild the eroded beach through the use of suitable sand directly taken from the sea bottom and afterwards released on the eroded beach (Garbin et al., 2012).

At the beginning for the beach nourishment of the littoral of Terracina was utilized a sandy limestone from inland quarries, absolutely unsuitable. This led to continuous washing out and narrowings of the beach that caused with time the silting up of the seabed. Such action, later revealed be ineffective and disastrous, led to the decision to utilize a sand with morphological and granulometric charac-

teristics as similar as possible to those of the eroded beach (Garbin et al., 2012).

In 2006 it was decided to carry out a kind of "soft" beach nourishment taking directly the sand from the so called "underwater quarry", located on relatively deep seabed off the coast depositing it directly on the eroded beaches (Figs. 1, 2). The most promising underwater cave was discovered about fifty miles north-west from Terracina, specifically off of Torvajanica (Rome) named "Cava sottomarina Torvaianica Sud Zona C2". This is just one of the many quarries of the continental marine shelf of Latium, used in the nourishment of other coasts such as Anzio, Ostia, Montalto di Castro, etc.. This site mainly differs from others in that the storage material was aspirated and drawn at a greater depth, around 110 meters depth.

This operation was divided into two different stages, the first was effected in 2006 for about two kilometers on the first half of the Ponente Beach and the second, to be performed the following year, on the other half up to the port. After the first stage on the shoreline, with the disappointment of the local community, the beach appeared covered with a large amount of pebbles and shells, thus putting

at risk the long tourist season. As a consequence the second stage was canceled (Giannelli et al., 2012).

A total of 1300 meters in length were interested in the beach, were obtained 66,000 square feet of new surface after the intervention with 460,000 cubic meters of sand poured. From the malacological point of view this large amount of material, both fossil and subfossil, is very interesting.

From the several collections made just after the first nourishment and during the immediately following months, altogether 144 taxa have been identified, of which 105 Gastropoda (73%), 37 Bivalvia (26%) and 2 Scaphopoda (1%).

MATERIAL AND METHODS

All species were collected directly along the shore line. Several species (for example *Neptunea contraria* (Linnaeus, 1771) are clearly fossils but for many others it was impossible to detect if it were the state fossil or subfossil. The nomenclature of the species has been updated according to WoRMS Editorial Board (2014).

RESULTS

Taxonomic list

Classis GASTROPODA Cuvier, 1797

Ordo VETIGASTROPODA Salvini-Plawen, 1980

Familia FISSURELLIDAE Fleming, 1822

Genus *Diodora* J.E.Gray, 1821
Diodora gibberula (Lamark, 1822)
Diodora graeca (Linnaeus, 1758) (Fig. 3)
Diodora cfr *demartiniorum* Buzzurro et Russo 2005 (Fig. 4)

Genus *Emarginula* Lamarck, 1801
Emarginula fissura (Linnaeus, 1758)

Familia TROCHIDAE Rafinesque, 1815

Genus *Clelandella* Winckworth, 1932
Clelandella miliaris (Brocchi, 1814)

Genus *Gibbula* Risso, 1826
Gibbula magus (Linnaeus, 1758)

Familia CALLIOSTOMATIDAE Thiele, 1924 (1847)

Genus *Calliostoma* Swainson, 1840
Calliostoma conulum (Linnaeus, 1758)
Calliostoma granulatum (Born, 1778)
Calliostoma laugieri (Payraudeau, 1826)
Calliostoma zizyphinum (Linnaeus, 1758)

Familia TURBINIDAE Rafinesque, 1815

Genus *Bolma* Risso, 1826
Bolma rugosa (Linnaeus, 1767)

Genus *Homalopoma* Carpenter, 1864
Homalopoma sanguineum (Linnaeus, 1758)

Familia PHASIANELLIDAE Swainson, 1840

Genus *Tricolia* Risso, 1826
Tricolia pullus (Linnaeus, 1758)

Ordo CAENOGASTROPODA Cox, 1960

Familia CERITHIIDAE Fleming, 1822

Genus *Cerithium* Bruguière, 1789
Cerithium alucaster (Brocchi, 1814)
Cerithium protractum (Bivona Ant. in Bivona And., 1838)
Cerithium vulgatum (Bruguière, 1792)

Familia SILIQUARIIDAE Anton, 1838

Genus *Tenagodus* Guettard, 1770
Tenagodus obtusus (Schumacher, 1817)

Familia TURRITELLIDAE Lovén, 1847

Genus *Turritella* Lamarck, 1799
Turritella turbona (Monterosato, 1877)

Familia TRIPHORIDAE Gray, 1847

Genus *Monophorus* Grillo, 1877
Monophorus perversus (Linnaeus, 1758)

Familia EPITONIIDAE Berry, 1910 (1812)

Genus *Epitonium* Röding, 1798
 Epitonium clathrus (Linnaeus, 1758)
 Epitonium turtonis (Turton, 1819)

Familia EULIMIDAE Philippi, 1853

Genus *Eulima* Risso, 1826
 Eulima glabra (da Costa, 1778)

Familia RISSOIDAE Gray, 1847

Genus *Alvania* Risso, 1826
 Alvania punctura (Montagu, 1803)

Familia VERMETIDAE Rafinesque, 1815

Genus *Thylacodes* Guettard, 1770
 Thylacodes arenarius (Linnaeus, 1758)

Familia APORRHAIDAE Gray, 1850

Genus *Aporrhais* da Costa, 1778
 Aporrhais pespelecani (Linnaeus, 1758)

Familia CALYPTRAEIDAE Lamarck, 1809

Genus *Calyptraea* Lamarck, 1799
 Calyptraea chinensis (Linnaeus, 1758)

Figure 1. Study area: littoral of Terracina, Latium, Italy (right); underwater quarry (left). Figure 2. Littoral of Terracina (Latium, Italy).

Fam ilia C A P U L ID A E Flem ing, 1822

Genus *Capulus* M ontfort, 1810
　　Capulus ungaricus (L in n a eus, 1758)

Fam ilia T R IV IID A E Troschel, 1863

Genus *Erato* R isso, 1826
　　Erato voluta (M ontagu, 1803)

Genus *Trivia* G ray, 1837
　　Trivia multilirata (G .B . S ow erby II, 1870)
　　(Figs. 5, 6)

Fam ilia C Y P R A EID A E R afinesque, 1815

Genus *Luria* Jousseaum e, 1884
　　Luria lurida (L in n a eus, 1758)

Genus *Naria* B roderip, 1837
　　Naria spurca (L in n a eus, 1758)

Genus *Schilderia* Tom lin, 1930
　　Schilderia achatidea (G ray in G .B . S ow erby I,
　　1837) (Figs. 7, 8)

Genus *Zonaria* Jousseaum e, 1884
　　Zonaria pyrum (G m elin, 1791) (Figs. 9, 10)

Fam ilia O V U LID A E Flem ing, 1822

Genus *Pseudosimnia* S child er, 1927
　　Pseudosimnia adriatica (G .B . S ow erby I, 1828)
　　(Figs. 11, 12)
　　Pseudosimnia carnea (P oiret, 1789) (Figs. 13, 14)

Genus *Simnia* R isso, 1826
　　Simnia spelta (L in n a eus, 1758) (Figs. 15, 16)

Fam ilia N A T IC ID A E G uilding, 1834

Genus *Euspira* A g assiz in J. S ow erby, 1837
　　Euspira fusca (B lainville, 1825)
　　Euspira guilleminii (P ayraudeau, 1826)
　　Euspira intricata (D onovan, 1804)
　　Euspira macilenta (P hilippi, 1844)

Genus *Naticarius* D um éril, 1805
　　Naticarius hebraeus (M artyn, 1786)
　　Naticarius stercus muscarum (G m elin, 1791)

Genus *Tectonatica* S acco, 1890
　　Tectonatica rizzae (P hilippi, 1844)

Fam ilia C A S S ID A E L atreille, 1825

Genus *Galeodea* L ink, 1807
　　Galeodea echinophora (L in n a eus, 1758)

Genus *Semicassis* M orch, 1852
　　Semicassis granulata undulata (G m elin, 1791)

Fam ilia R A N E L L ID A E G ray, 1854

Genus *Cabestana* R öding, 1798
　　Cabestana cutacea (L in n a eus, 1767) (Fig. 17)

Genus *Charonia* G istl, 1847
　　Charonia lampas (L in n a eus, 1758)

Genus *Monoplex* P erry, 1810
　　Monoplex corrugatum (L am arck, 1816)
　　Monoplex parthenopeum (V on S alis, 1793)

Genus *Ranella* L am arck, 1816
　　Ranella olearium (L in n a eus, 1758)

Fam ilia B U R S ID A E T hiele, 1925

Genus *Bursa* R öding, 1798
　　Bursa scrobilator (L in n a eus, 1758) (Figs. 18, 19)

Fam ilia M U R IC ID A E R afinesque, 1815

Genus *Babelomurex* C oen, 1922
　　Babelomurex benoiti (T iberi, 1855)

Genus *Bolinus* P usch, 1837
　　Bolinus brandaris (L in n a eus, 1758)

Genus *Dermomurex* M onterosato, 1890
　　Dermomurex scalaroides (B lainville, 1829)
　　(Fig. 20)

Genus *Hadriania* B ucquoy et D autzem berg, 1882
　　Hadriania craticula (B ucquoy, D autzem berg et
　　D ollfus, 1882) (Fig. 21)

Genus *Hexaplex* P erry, 1810
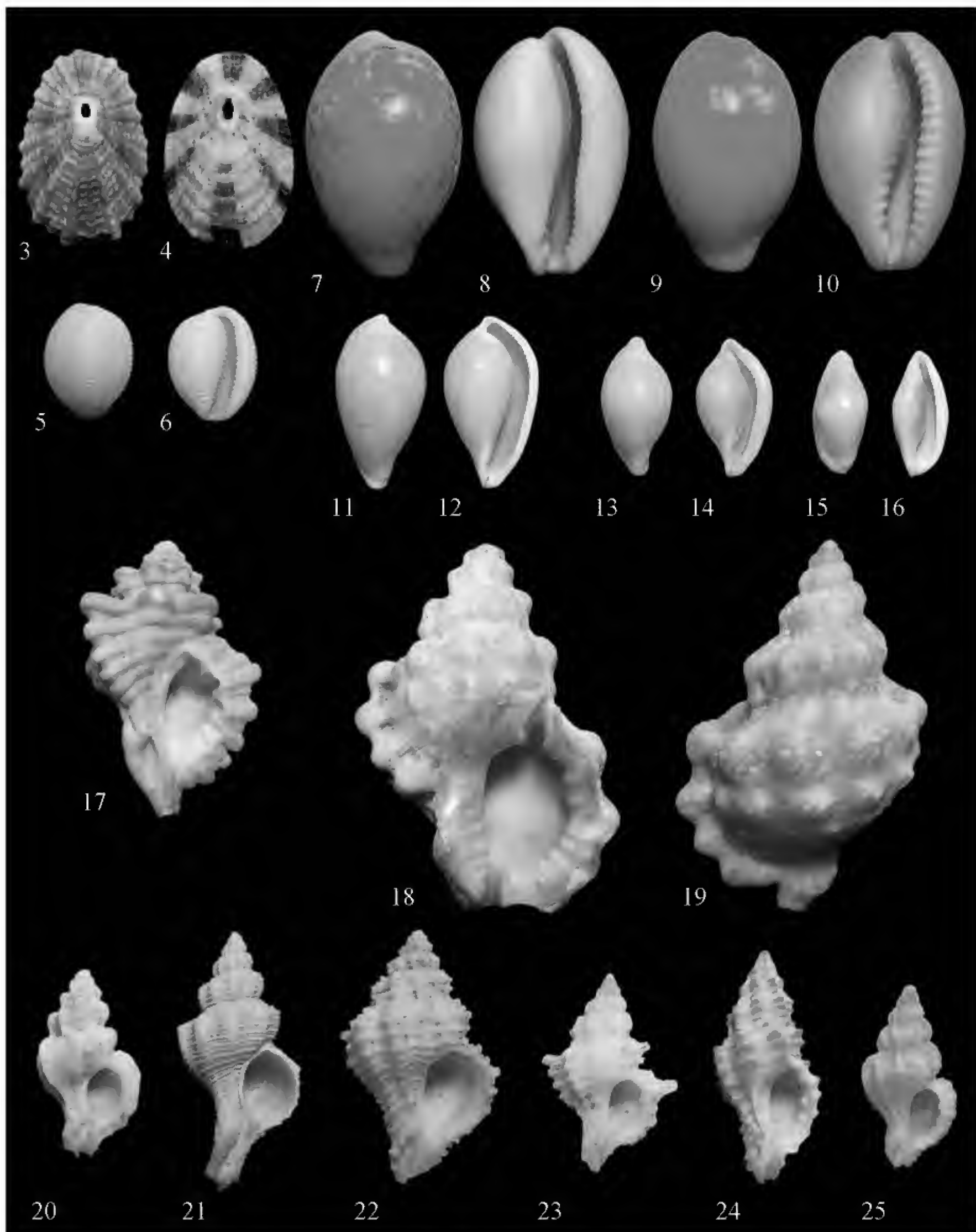　　*Hexaplex trunculus* (L in n a eus, 1758)

Fig. 3. *Diodora graeca*, h: 25.6 mm. Fig. 4. *Diodora* cfr. *demartiniorum*, h: 25.3 mm. Figs. 5, 6. *Trivia multilirata*, h: 12.2 mm. Figs. 7, 8. *Schilderia achatidea*, h: 38 mm. Figs. 9, 10. *Zonaria pyrum*, h: 34.8 mm. Figs. 11, 12. *Pseudosimnia adriatica*, h: 23.1 mm. Figs. 13, 14. *P. carnea*, h: 16.2 mm. Figs. 15, 16. *Simnia spelta*, h: 13.6 mm. Fig. 17. *Cabestana cutacea*, h: 44.2 mm. Fig. 18, 19. *Bursa scrobilator*, h: 49.2 mm. Fig. 20. *Dermomurex scalaroides*, h: 17.4 mm. Fig. 21. *Hadriania craticula* h: 31.7 mm. Fig. 22. *Hirtomurex squamosus*, h: 26.5 mm. Fig. 23. *Murexul aradasii*, h: 12 mm. Fig. 24. *Muricopsis cristata*, h: 21 mm. Fig. 25. *Ocinebrina helleri*, h: 16.3 mm.

Genus *Hirtomurex* Coen, 1922
    Hirtomurex squamosus (Bivona Ant. in Bivona
    And., 1838) (Fig. 22)

Genus *Murexul* Iredale, 1915
    Murexul aradasii (Monterosato in Poirieri,
    1883) (Fig. 23)

Genus *Muricopsis* Bucquoy et Dautzemberg, 1882
    Muricopsis cristata (Brocchi, 1814) (Fig. 24)

Genus *Ocenebra* Gray, 1847
    Ocenebra erinaceus (Linnaeus, 1758)

Genus *Ocinebrina* Jousseaume, 1880
    Ocinebrina edwardsi (Payraudeau, 1826)
    Ocinebrina helleri (Brusina, 1865) (Fig. 25)

Genus *Pagodula* Monterosato, 1884
    Pagodula echinata (Kiener, 1840) (Fig. 26, 27)

Genus *Trophonopsis* Bucquoy, Dautzemberg et
Dollfuss, 1882
    Trophonopsis muricata (Montagu, 1803)

Genus *Typhinellus* Jousseaume, 1880
    Typhinellus labiatus (de Cristofori et Jan, 1832)
    (Fig. 28, 29)

Familia MARGINELLIDAE Fleming, 1828

Genus *Volvarina* Hinds, 1844
    Volvarina mitrella (Risso, 1826)

Familia MITRIDAE Swainson, 1829

Genus *Mitra* Lamarck, 1798
    Mitra cornicula (Linnaeus, 1758)
    Mitra zonata (Marryat, 1818)

Familia COSTELLARIIDAE Mac Donald, 1860

Genus *Vexillum* Röding, 1798
    Vexillum ebenus (Lamarck, 1811)
    Vexillum granum (Forbes, 1844)
    Vexillum tricolor (Gmelin, 1791)

Familia BUCCINIDAE Rafinesque, 1815

Genus *Euthria* Gray, 1850
    Euthria cornea (Linnaeus, 1758)

Genus *Neptunea* Röding, 1798
    Neptunea contraria (Linnaeus, 1771)

Familia NASSARIIDAE Iredale, 1916 (1835)

Genus *Nassarius* Duméril, 1805
    Nassarius corniculum (Olivi, 1792)
    Nassarius incrassatus (Strom, 1768)
    Nassarius nitidus (Jeffreys, 1867)
    Nassarius pygmaeus (Lamarck, 1822)

Familia COLUMBELLIDAE Swainson, 1840

Genus *Mitrella* Risso, 1826
    Mitrella coccinea (Philippi, 1836)
    Mitrella minor (Scacchi, 1836)
    Mitrella scripta (Linnaeus, 1758)

Familia FASCIOLARIIDAE Gray, 1853

Genus *Fusinus* Rafinesque, 1815
    Fusinus rostratus (Olivi, 1792) (Fig. 30)

Familia CLATHURELLIDAE H. Adams et A.
Adams, 1858

Genus *Comarmondia* Monterosato, 1884
    Comarmondia gracilis (Montagu, 1803)

Familia MITROMORPHIDAE Casey, 1904

Genus *Mitromorpha* Carpenter, 1865
    Mitromorpha karpathoensis (Nordsiek, 1969)
    Mitromorpha mediterranea (Mifsud, 2001)

Familia MANGELIIDAE P. Fisher, 1883

Genus *Bela* Gray, 1847
    Bela nebula (Montagu, 1803)

Genus *Mangelia* Risso, 1826
    Mangelia costata (Pennant, 1777)
    Mangelia costulata (Risso, 1826)
    Mangelia sp.

Familia DRILLIIDAE Olsson, 1964

Genus *Crassopleura* Monterosato, 1884
    Crassopleura maravignae (Bivona Ant. in
    Bivona And., 1838)

Familia CLAVATULIDAE Gray, 1853

Genus *Fusiturris* Thiele, 1929
  Fusiturris similis (Bivona Ant. in Bivona And., 1838)

Familia RAPHITOMIDAE Bellardi, 1875

Genus *Raphitoma* Bellardi, 1847
  Raphitoma cfr. *atropurpurea* (Fig. 31)
  Raphitoma cfr. *echinata* (Fig. 32)
  Raphitoma leufroyi (Michaud, 1828) (Fig. 33)
  Raphitoma sp. 1 (Fig. 34)
  Raphitoma sp. 2

Ordo HETEROSTROPHA P. Fischer, 1885

Familia ARCHITECTONICIDAE J.E. Gray in M.E. Gray, 1850

Genus *Discotectonica* Marwick, 1931
  Discotectonica discus (Philippi, 1844) (Figs. 35, 36)

Genus *Heliacus* d'Orbigny, 1842
  Heliacus fallaciosus (Tiberi, 1872) (Fig. 37)

Genus *Pseudotorinia* Sacco, 1892
  Pseudotorinia architae (O.G. Costa, 1841) (Figs. 38-40)

Familia MATHILDIDAE Dall, 1889

Genus *Mathilda* Semper, 1865
  Mathilda quadricarinata (Brocchi, 1814)

Familia PYRAMIDELLIDAE Gray, 1840

Genus *Euparthenia* Thiele, 1931
  Euparthenia bulinea (Lowe, 1841) (Figs. 41, 42)

Familia ACTEONIDAE d'Orbigny, 1843

Genus *Acteon* Montfort, 1810
  Acteon tornatilis (Linnaeus, 1758)

Familia RINGICULIDAE Philippi, 1853

Genus *Ringicula* Deshayes, 1838
  Ringicula auriculata (Ménard de la Groye, 1811)

Ordo CEPHALASPIDEA P. Fischer, 1883

Familia CYLICHNIDAE H. Adams et A. Adams, 1854

Genus *Cylichna* Lovén, 1846
  Cylichna cylindracea (Pennant, 1777)

Familia SCAPHANDRIDAE G.O. Sars, 1878

Genus *Scaphander* Montfort, 1810
  Scaphander lignarius (Linnaeus, 1758)

Ordo UMBRACULIDA Odhner, 1939

Familia UMBRACULIDAE Dall, 1889 (1827)

Genus *Umbraculum* Schumacher, 1817
  Umbraculum umbraculum (Lightfoot, 1786)

Classis BIVALVIA

Ordo SOLEMYOIDA Dall, 1889

Familia NUCULIDAE Gray, 1824

Genus *Nucula* Lamarck, 1799
  Nucula nucleus (Linnaeus, 1758)
  Nucula sulcata (Bronn, 1831)

Familia NUCULANIDAE H. Adams et A. Adams, 1858 (1854)

Genus *Nuculana* Link, 1807
  Nuculana pella (Linnaeus, 1767)

Ordo ARCOIDA Stoliczka, 1871

Familia ARCIDAE Lamarck, 1809

Genus *Anadara* Gray, 1847
Anadara polii (Mayer, 1868)

Genus *Arca* Linnaeus, 1758
  Arca tetragona (Poli, 1795)

Familia GLYCYMERIDIDAE Dall, 1908 (1847)

Genus *Glycymeris* da Costa, 1778
    Glycymeris glycymeris Linnaeus (1758)

Ordo PECTINOIDA Gray, 1854

Familia PECTINIDAE Rafinesque, 1815

Genus *Aequipecten* P. Fisher, 1886
    Aequipecten commutatus (Monterosato, 1875)
    (Fig. 43)
    Aequipecten opercularis (Linnaeus, 1758)
    (Fig. 44)

Genus *Manupecten* Monterosato, 1872
    Manupecten pesfelis (Linnaeus, 1758)

Genus *Mimachlamys* Iredale, 1929
    Mimachlamys varia (Linnaeus, 1758) (Fig. 45)

Genus *Pecten* O.F. Muller, 1776
    Pecten jacobeus (Linnaeus, 1758) (Fig. 46)
    Pecten maximus (Linnaeus, 1758) (Fig. 47)

Genus *Pseudamussium* Morch, 1853
    Pseudamussium clavatum (Poli, 1795) (Fig. 48)

Genus *Similipecten* Winckworth, 1932
    Similipecten similis (Laskey, 1811)

Genus *Talochlamys* Iredale, 1935
    Talochlamys multistriata (Poli, 1795) (Fig. 49)

Familia SPONDYLIDAE Gray, 1826

Genus *Spondylus* Linnaeus, 1758
    Spondylus gaederopus (Linnaeus, 1758)

Ordo OSTREOIDA Férussac, 1822

Familia OSTREIDAE Rafinesque, 1815

Genus *Ostrea* Linnaeus, 1758
    Ostrea edulis (Linnaeus, 1758)

Ordo LUCINOIDA Gray, 1854

Familia LUCINIDAE Fleming, 1828

Genus *Lucinella* Monterosato, 1884
    Lucinella divaricata (Linnaeus, 1758)

Genus *Lucinoma* Dall, 1901
    Lucinoma borealis (Linnaeus, 1767)

Genus *Myrtea* Turton, 1822
    Myrtea spinifera (Montagu, 1803)

Ordo VENEROIDA Gray, 1854

Familia CHAMIDAE Lamarck, 1809

Genus *Chama* Linnaeus, 1758
    Chama gryphoides (Linnaeus, 1758)

Familia CARDITIDAE Férussac, 1822

Genus *Centrocardita* Sacco, 1899
    Centrocardita aculeata (Poli, 1795)

Familia ASTARTIDAE d'Orbigny, 1844 (1840)

Genus *Astarte* J.de C. Sowerby, 1816
    Astarte fusca (Poli, 1795)

Familia CARDIIDAE Lamarck, 1809

Genus *Laevicardium* Swainson, 1840
    Laevicardium oblongum (Gmelin, 1791)

Genus *Papillicardium* Sacco, 1899
    Papillicardium papillosum (Poli, 1795)

Genus *Parvicardium* Monterosato, 1884
    Parvicardium minimum (Philippi, 1836)

Familia MACTRIDAE Lamarck, 1809

Genus *Lutraria* Lamarck, 1799
    Lutraria lutraria (Linnaeus, 1758)
    Lutraria oblonga (Gmelin, 1791)

Familia TELLINIDAE Blainville, 1814

Genus *Tellina* Linnaeus, 1758
    Tellina serrata (Brocchi, 1814)

Familia SOLECURTIDAE d'Orbigny, 1846
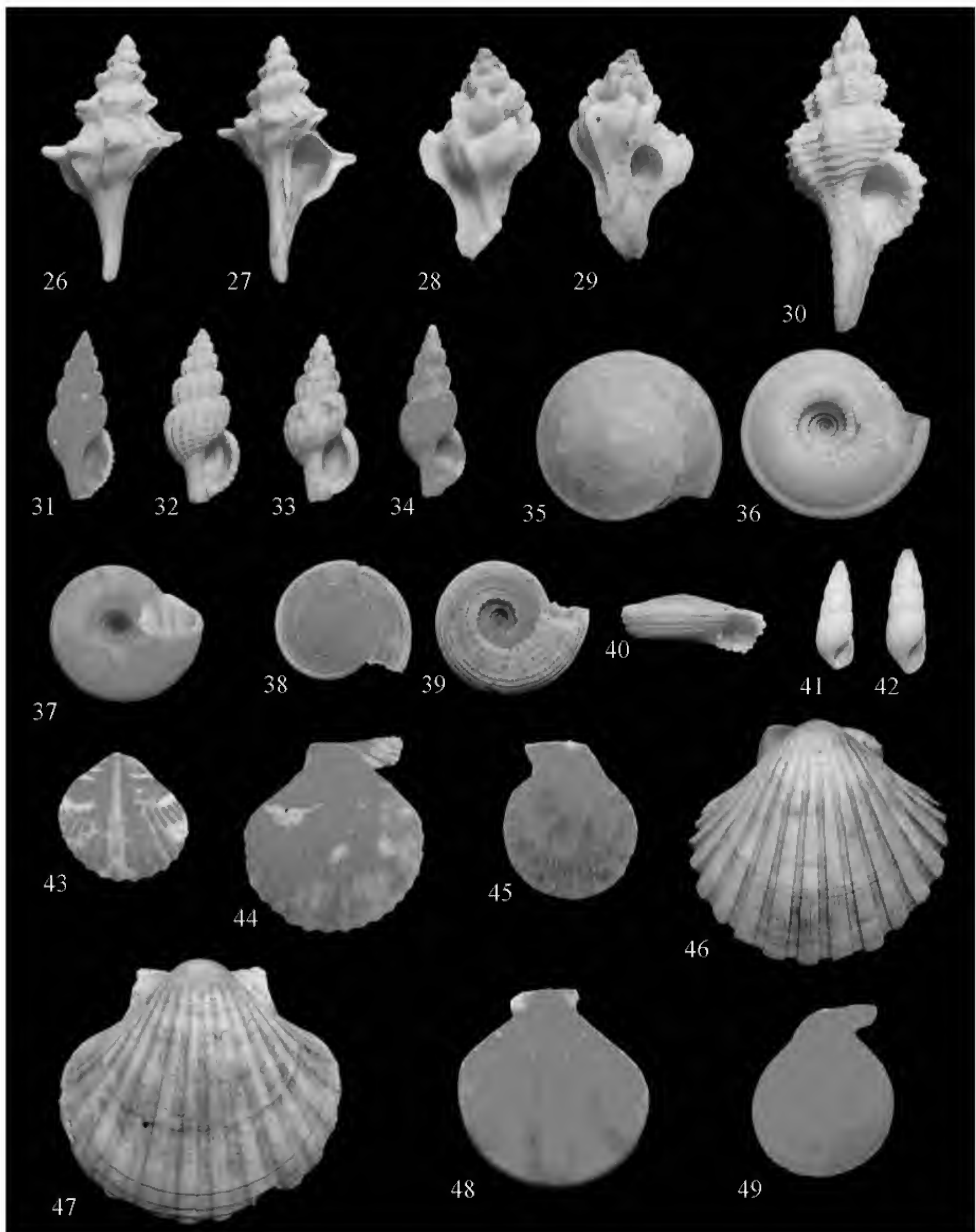
Figs. 26, 27. *Pagodula echinata*, h: 19.8 mm. Figs. 28, 29. *Typhinellus labiatus*, h: 18.1 mm. Fig. 30. *Fusinus rostratus*, h: 36.2 mm. Fig. 31. *R.* cfr. *atropurpurea*, h: 15.4 mm. Fig. 32. *R.* cfr. *echinata*, h: 21.6 mm. Fig. 33. *R. leufroyi*, h: 22 mm. Fig. 34. *Raphitoma* sp., h: 22.7 mm. Figs. 35, 36. *Discotectonica discus*, h: 26.6 mm. Fig. 37. *Heliacus fallaciosus*, h: 16.3 mm. FigS. 38-40. *Pseudotorinia architae*, h: 8.7 mm. Figs. 41, 42. *Euparthenia bulinea*, h: 13.9 mm. Fig. 43. *Aequipecten commutatus*, h: 24.8 mm. Fig. 44. *A. opercularis*, h: 33.9 mm. Fig. 45. *Mimachlamys varia*, h: 26.4 mm. Fig. 46. *Pecten jacobeus*, h: 61 mm. Fig. 47. *Pecten maximus*, h: 74.9 mm. Fig. 48. *Pseudamussium clavatum*, h: 30.4 mm. Fig. 49. *Talochlamys multistriata*, h: 24.7 mm.

Genus *Solecurtus* Blainville, 1824
     Solecurtus scopula (Turton, 1822)

Familia VENERIDAE Rafinesque, 1815

Genus *Chamelea* Morch, 1853
     Chamelea striatula (da Costa, 1778)

Genus *Clausinella* Gray, 1851
     Clausinella fasciata (da Costa, 1778)

Genus *Globivenus* Coen, 1934
     Globivenus effossa (Philippi, 1836)

Genus *Pitar* Romer, 1857
     Pitar rudis (Poli, 1795)

Genus *Timoclea* Brown, 1827
     Timoclea ovata (Pennant, 1777)

Genus *Venus* Linnaeus, 1758
     Venus nux (Gmelin, 1791)

Ordo ANOMALODESMATA Dall, 1889

Familia CUSPIDARIIDAE Dall, 1886

Genus *Cuspidaria* Nardo, 1840
     Cuspidaria cuspidata (Olivi, 1792)

Classis SCAPHOPODA

Ordo DENTALIIDA Starobogatov, 1974

Familia DENTALIIDAE Children, 1834

Genus *Antalis* H. Adams et A. Adams, 1854
     Antalis dentalis (Linnaeus, 1758)
     Antalis inaequicostata (Dautzenberg, 1891)

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On the systematic position of "*Cima*" *melitensis* Mifsud, 1998, with erection of the new genus *Mifsudia* (Heterobranchia Cimidae)

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ABSTRACT   Based on teleoconch and, especially, protoconch features, the new genus *Mifsudia* is erected for *Cima melitensis* Mifsud, 1998 and placed in the family Cimidae. The protoconch is hyperstrophic, as in the other cimids. At least, two European fossil species (*Cima gantensis* Bandel, 2005, from the Middle Eocene of Hungary and *Murchisonella* cf. *obtusa* Gougerot & Le Renard, 1978 from Early Oligocene of France) are also included in the new genus. *Mifsudia melitensis* (Mifsud, 1998) comb. nov., originally described from Malta, is here recorded for the first time from Lampedusa Island, Alboran Sea and the coasts of Mauritania (West Africa).

KEY WORDS   Gastropoda; *Cima*; *Murchisonella*; *Mifsudia*; Mediterranean Sea; Western Africa.

INTRODUCTION

During the in progress revision of the genus *Cima* Chaster, 1896 (Heterobranchia Cimidae) in the Mediterranean Sea, we examined several specimens of Mediterranean and Atlantic "*Cima*" and recorded notable differences on the protoconchs. This drove us to investigate in depth this complex group of Heterostropha and allowed recognizing two different typologies of protoconchs: the first one is globular, tipical of *Cima* sensu strictu (e.g. *Cima minima* Jeffreys, 1858, Fig. 5), the second one is clearly hyperstrophic (e.g. *Cima melitensis* Mifsud, 1998, Figs. 1– 4). This latter type, resembles the protoconch of some *Murchisonella* Mørk, 1875 (Warén, 2013) but is clearly distinguishable. This double typology of protoconch can be recognized in the fossil species referred to "*Cima*" (Warén, 2013).

The known species attributable to the genus *Cima*, for the Mediterranean and European sea waters (*C. minima*; *C. cylindrica* Jeffreys, 1856; *C. cuticulata* Warén, 1993; *C. inconspicua* Warén, 1993; *C. apicisbelli* Rolan, 2003) consist of a morphologically homogeneous group. One exception is "*Cima*" *melitensis*, described by Mifsud (1998) from a limited number of specimens coming from 80–100 m deep Malta's waters, and lacking of soft tissue. This species is characterized by a pyramidelliform teloconch, surmounted by a protoconch that seems truncated; at a first sight the shell resembles closely *Odostomia* Fleming, 1813 or *Liostomia* G.O. Sars, 1878.

The analysis at SEM of some shells highlighted a very peculiar protoconch, certainly different from Pyramidellidae: after an extremely small nucleus (about 27 μm), the protoconch unwinds on an horizontal axis for half a rotation; then it raises, creating a small prominence easy visible in lateral view (Fig. 4); then it goes down and continues with a normal dextrorse envelopment. This kind of protoconch is called hyperstrophic and is typical of some families of Heterobranchia (Heterostropha) such as Architectonicidae, Murchisonellidae, etc. Basing on these morphological features we believe that the collocation of this species into the genus *Cima* is incorrect.

Chaster (1896) instituted the subgenus *Cima* (ex Monterosato) without any description, just declaring that "... *which Jeffreys described as* Odostomia minima, *for which species and the closely allied but quite distinct* Jeffreysia cylindrica *Jeffr., Monterosato proposes the sub-genus* Cima, *a separation with which I entirely concur*."

One first problem is to determine which is the type species of *Cima*. Following Warén (1993) this is *Odostomia minima* Jeffreys, 1858, while Bandel (2005) indicates as type species *Jeffreysia cylindrica* Jeffreys, 1856. The work of Warén (1993) is earlier and then the correct type species for *Cima* is *Odostomia minima*.

Van Aartsen (1981) validates the separation between *Cima* and *Pherusina* Norman, 1888 (=*Aclis* Lovén, 1846), proposed by Monterosato, but, basing on morphological features such as the shape of peristome, the embrional whorls, the clear flexuous growth lines, he considers valid the position of the genus in Aclididae. The same opinion is shared by Fretter & Graham (1982), that nevertheless do not exclude to put this genus in a new, to be created, family Cimidae. Afterwards Graham (1988) preserves the collocation of *Cima* in Aclididae.

Warén (1993), mainly on anatomical base, puts *Cima* in the new monogeneric family Cimidae, into the subclass Heterobranchia.

Bouchet & Rocroi (2005) maintain *Cima* in the Cimidae family, into the Heterobranchia, but without further collocation. Bandel (2005) discusses the collocation of many genera, now included in Heterostropha, such as *Aclis* Lovén, 1846, *Hemiaclis* G.O. Sars, 1878, *Graphis* Jeffreys, 1867, *Cima*, *Murchisonella* Mörch, 1875, and *Ebala* Gray, 1847. The result, based on anatomy, shell morphol-

ogy and evolutionary trend, is that all these genera have to be included in different families. In particular, *Cima* is re-positioned in Streptacididae, a family that includes other fossil genera from the Paleozoic. *Murchisonella* is included in the Donaldinidae family, including fossil genera from Carboniferous. The Ebalidae (= Anisocyclidae) is considered separated family.

Recently, Peñas & Rolán (2013) reviewed the genus *Murchisonella* and proposed using the genus *Pseudoaclisina* Yoo, 1994 for the species with rounded coils; in the same year Warén (2013) published a study about Murchisonellidae, where he analyzed this family and other similar ones, basing on genetic, anatomical and palaeontological features, providing guidelines on these small Heterobranchia for future studies.

The morphological differences that all the Authors recognize between *Cima* and *Murchisonella* regard the shape of the protoconch and the presence of growth lines: *Cima* does not have the deep sinus close to the suture that characterizes *Murchisonella*. Moreover, *Murchisonella* has a scalariform profile, while in *Cima* it is rounded.

Considering the *Cima* species, both the type species *Odostomia minima* Jeffreys, 1858 and then *Jeffreysia cylindrica* Jeffreys, 1856 present a globular and slightly inclined protoconch (Figs. 5, 7, 8), completely different from those of *melitensis*.

The features of the protoconch of *C. melitensis* bring the species close to the genus *Murchisonella*, whose type species *Murchisonia* (*Murchisonella*) *spectrum* Mørk, 1875 (Fig. 9), comes from the Caribbean area (Redfern, 2001). This genus is characterized by an aclidiform shell, densely striated in the middle and inferior part of the whorls, with a sinus in the upper part of the external peristome edge, and hyperstrophic protoconch.

The only species attributed to this genus, reported in the Mediterranean, is *Murchisonella mediterranea* Peñas & Rolán, 2013 (= *Murchisonella columna* Auctores not Hadely, 1807).

With both these species *C. melitensis* shares only the protoconch and not the growth style or the shape of the whorls that are in common with *Cima*. Thus, we think that *C. melitensis* has to be attributed to a distinct genus, but none of the known ones, both from fossil and living records, seems suitable. So we believe it is necessary to institute a new genus.
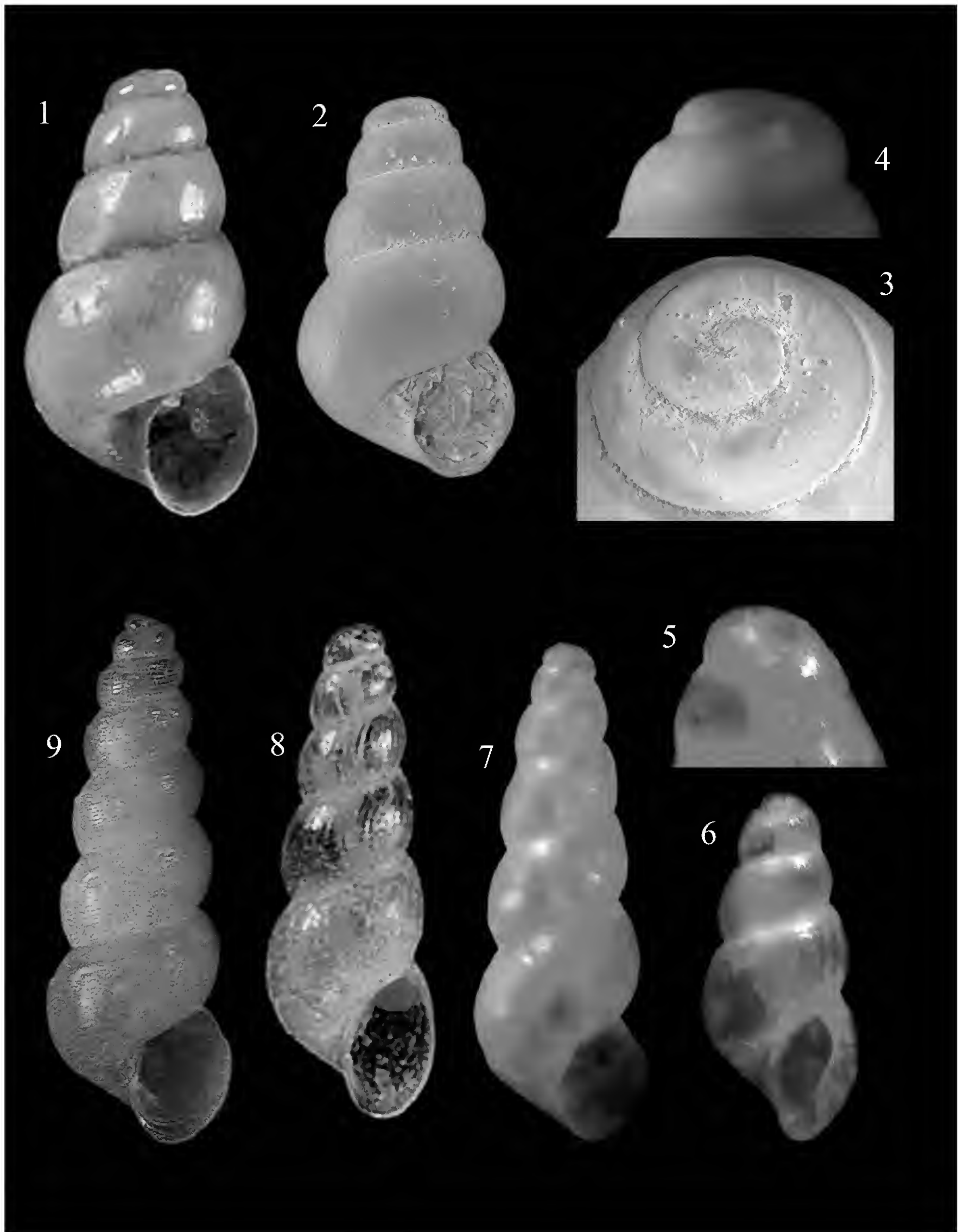
Figure 1. *Mifsudia melitensis*, Mauritania, -80/100 m (1.1 mm). Figure 2. *Mifsudia melitensis*, Mauritania, -80/100 m (0.98 mm). Figure 3. *Mifsudia melitensis*, Mauritania, -80/100 m, protoconch of shell in Fig 2. Figure 4. *Mifsudia melitensis*, protoconch, lateral view, Mauritania, -80/100 m. Figure 5. *Cima minima*, protoconch, Giannutri Island, Grosseto, Italy, -18 m. Figure 6. *Cima* sp., Getares, Algeciras, Spain, beach (0.86 mm). Figure 7. *Cima* cf. *cylindrica*, Sorrento, Naples, Italy, -50/60 m (1.48 mm). Figure 8. *Cima cylindrica*, Levanzo Island, Trapani, Italy, -31 m (1.45 mm). Figure 9. *Murchisonella spectrum*, Varadero, Bahía de Cochinos (Cuba), -10 m (1.4 mm).

ACRONYMS. Franco Gubbioli collection, Marbella, Málaga, Spain = FG. Paolo Mietto collection, Vicenza, Italy = PM. Italo Nofroni collection, Rome, Italy = IN. Ermanno Quaggiotto collection, Longare, Vicenza, Italy = EQ.

RESULTS

SYSTEMATIC

Class GASTROPODA Cuvier, 1797

Subclass HETEROBRANCHIA Gray, 1840 (unassigned)
Infraclass HETROBRANCHIA Gray, 1840
Family CIMIDAE Warén, 1993

Genus *Mifsudia* n. gen.

TYPE SPECIES. *Cima melitensis* Mifsud, 1998: Figs. 4, 5.

EXAMINED MATERIAL. *"Cima" melitensis*. Lampedusa Island, Cala Calandra, -30 m, legit M. Oliverio, 1 shell (IN). Between Estepona (Malaga, Spain) e Tetuan (Morocco), -25/35 m, 1 shell (IN). Mauritania (West Africa, Atlantic Ocean), - 80/100 m, more than 40 shells, legit F. Gubbioli, (FG, PM, IN, EQ). All inedited reports. Malta, Golden Bay, -100/120 m, legit F. Carmona, 1 shell (EQ). *Cima minima*: more than 60 shells from all the Mediterranean Sea, from 0 to 180 m of depth (PM, IN, EQ).

Cima cylindrica. More than 60 shells from all the Mediterranean Sea, from 0 to 100 m of depth (PM, IN, EQ).

Cima sp. 2 shells from Getares (Algeciras. Spain), beach, inedited report (IN).

Murchisonella spectrum. Varadero (Cuba, Caraib Sea), beach, legit C. Petrella, 1 shell (EQ). Bahía de Cochinos (Cuba, Carribean), debris -10 m, legit M. Chiodi, 7 shells (IN).

Murchisonella mediterranea. Aydincik (Turkey), -27 m, , legit M. Oliverio, 1 shell (IN).

Murchisonella sp. Watamu (Kenia, Indian Ocean), -32 m, legit L. Contessini, 1 shell (IN). Shaiab

Rumi (Sudan, Red Sea), - 60 m, legit M. Oliverio, 1 shell (IN).

DESCRIPTION. Small shell, white, bright, lacking in the spiral sculpture, widely umbilicate, with the shape similar to *Odostomia*; rounded whorl with growth lines flexuous but lacking in the subsutural sinus. External peristome edge thin and sharp, lacking in sinus. Hyperstrophic protoconch with probable planctotrophic development.

ETIMOLOGY. The name has been coined in honor of Constantine Mifsud, the well known Maltese malacologist, discoverer of *C. melitensis*.

REMARKS. Composition of the genus:
Mifsudia melitensis Mifsud, 1998 - living, Mediterranean Sea and Atlantic Ocean
Mifsudia gantensis Bandel, 2005 - fossil, Middle Eocene, Hungary (= *Cima gantensis*)
Mifsudia sp. (= *Murchisonella* n. sp.? pro *Murchisonella* cf. *obtusa* Gougerot & Le Renard, 1978) fossil, Early Oligocene, France, see below.

DISCUSSION

As previously discussed, the new genus *Mifsudia* n. gen. differs from *Cima* for the shape of the protoconch, hyperstrophic and not globular; the shape of the growth lines, sinuous (sigmoids) but always lacking in the subsutural sinus. The rounded shape of the whorls is similar in both genera.

Mifsudia n. gen. and *Murchisonella* share the same typology of hyperstrophic protoconch but not the shape of the whorls, that in the latter is clearly angular, nor the shape of the growing lines that in *Murchisonella* is sigmoid and characterized by a deep sinus in the subsutural area.

These differences occur also in the fossil forms, at least from Lutetian (Middle Eocene).

Thus, to be included in *Mifsudia* there are:

1) *Cima gantensis* Bandel, 2005 from the Middle Eocene of Hungary.
2) *Murchisonella* n. sp.? pro *Murchisonella* cf. *obtusa* (in Gougerot & Le Renard, http.//www.somali.asso.fr/fossils/biotaxis.php, fische batch LR-71951) from the Early Oligocene (Stampiano Auct.) of France.

According to Le Renard (http://www.somali.asso.fr/fossils/biotaxis.php), Janssen A.W. (1984), because of

the features of the protoconch and of the growth lines, have to be referred to *Cima* the fossil species *Cima gougeroti* Le Renard, in schedis, from the Lutetian of the Paris Basin (http.//www.somali.asso.fr/fossils/biotaxis.php, batch 60859 and 61595), *Cima microscopica* Le Renard, in schedis, from the Lutetian and "Biarritzian" of the Paris Basin (http.//www.somali.asso.fr/fossils/biotaxis.php, batch 73241), *Aclis* (*Stilbe*) *proneglecta* R. Janssen, 1978 from the Upper Oligocene of Glimmerode (Germany), *Aclis* (*Stilbe*) *neglecta* A.W. Janssen, 1969 from the Miocene of Dingden (Germany).

According to Pachaud & Le Renard (1995) should be referred to *Murchisonella* the fossil species *Aciculina emarginata* Deshayes, 1861, *Murchisonella densesulcata* Gougerot, 1966 and *M. obtusa* Gougerot & Le Renard, 1978, all from the Lutetian of the Paris Basin.

The presence of clear distinctive characteristics among these three genera, highlighted since the Lutetian, supports the validity of the new genus *Mifsudia*.

About what concerns the systematic collocation of the new genus, we have to confess some embarrassment because the previous Authors used several and different criteria for the collocation of the genera at the family level. We think that what proposed by Bandel (2005) is not completely shareable because we separate *Mifsudia* from *Cima* due to the protoconch shape, without considering other anatomical characteristics.

Without starting a systematic discussion, it has to be considered that Bandel (2005) and Warén (2013) used as criterion the teloconch feature rather than the protoconch. Following this rule, the absence of the characteristic sinus in the growing lines, typical of *Murchisonella* and *Pseudoaclisina*, gives credit for the collocation of *Mifsudia* in Cimidae.

ACKNOWLEDGEMENTS

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Natural values, coastal and marine ecosystems of the Circeo National Park: conservation priorities

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ABSTRACT The variety of environments that characterizes the Circeo National Park must also take into account, in addition to the terrestrial natural values that are present, even the importance of marine and coastal stretches that currently do not benefit from a similar regime of protection, preserving instead important elements of wealth for marine biodiversity. This added value is represented in a particular way by the presence of *Posidonia oceanica* (L.) Delile, 1813, habitat of Community interest. The proposal of the Plan of the Park to extend to the sea The Circeo National Park would help to protect and enhance areas for the most part already included in the Natura 2000 network that could be handled in a unified manner by the Park providing for their conservation through various management interventions. Another proposal involves, instead of creating a true marine protected area, encompassing the whole *Posidonia* meadows present both in the northern section of the coast and in the south, between San Felice and Terracina and, hopefully also the stretch of sea that surrounds the island of Zannone (therefore including the SPAs area regarding the Pontine Archipelago).

INTRODUCTION

The Circeo National Park, established by Law No. 285 of 25 January 1934 in order to "... protect and improve the flora and fauna, preserving the special geological formations and the beauty of the landscape and promote the development of tourism," after have suffered several perimetral changes over the years is now extended for a little less than 9000 ha., while protecting currently only a strip of land characterized by the presence of five different environmental situations that make up the rich mosaic that characterizes it: the plain forest, the promontory, the coastal dune, coastal lakes and the adjoining wetlands, the Island of Zannone part of Pontine Islands.

The importance and value of the protected area is especially evidenced by the layering of several legislative instruments at regional, national, Community and international level that protect the territory and biological forms and abiotic ones preserved in it.

Regulatory instruments at the regional, national, European and international level

Institution of the CNP with Law no. 285 of January 25, 1934

Institution of five natural reserves of the State (1971-1979)

Bonn Convention - conservation of migratory wildlife species

Berne Convention - Wildlife and conservation of the natural environment in Europe

Ramsar Convention - conservation of wetlands of international interest (presence of 3 sites included)

CITES - regulating international trade in endangered species of flora and fauna

Directive 79/409/EEC (Directive 2009/147/EC "Birds Directive")

"Habitats Directive" (92/43/EEC)

Framework law on protected areas 394/91

Act No 157 of 11 February 1992 (Omeoterma wildlife protection and hunting)

Regional Law 18/88 (protection of minor fauna)

Presence of 2 IBA sites (Birdlife International)

SPA IT6040015 Parco Nazionale del Circeo

SPA IT6040019 Isole di Ponza, Palmarola, Zannone, Ventotene e S. Stefano

SCI IT6040013 Lago di Sabaudia

SCI IT6040012 Laghi di Fogliano, Monaci, Caprolace e Pantani dell'Inferno

SCI IT6040014 Foresta Demaniale del Circeo

SCI IT6040016 Promontorio del Circeo (Quarto Caldo)

SCI IT6040017 Promontorio del Circeo (Quarto Freddo)

SCI IT6040018 Dune del Circeo

SCI IT6040020 Isole di Palmarola e Zannone

The Circeo National Park includes 5 nature reserves established from 1971 to 1979. Among the international conventions ratified by our country that involve it directly, we can mention the Bonn Convention on the Conservation of Migratory Species of wildlife, the Berne Convention for the conservation of the natural environment in Europe and the wild species, the Ramsar Convention for wetlands of international value, the Washington Convention (CITES) for the regulation of international trade of endangered species of flora and fauna, the Habitats and Birds Directives, the framework law on protected areas 394/91, the law number 157 of 1992 for the protection of homeothermic wildlife from hunting, and even the regional law 18/88 for the protection of minor fauna. Finally, we must remember both the presence of two Important Bird Areas as well, with regard to Community directives, the two SPAs and the seven SCIs that insist throughout the area going to generate a multilayered system of protection at different levels both normative and territorial, which bear witness to the importance of these places. Nevertheless, thought it was the first, and for a long time the only coastal national park in Italy, the sea has always been regarded in second place in the environmental protection policy.

DISCUSSION

In spite of the attention has always been focused solely on terrestrial environments of the National Park of Circeo, of great importance is also the stretch of sea between Capo Circeo and the Pontine Islands. In this area were reported indeed marine mammals as bottlenose dolphin (*Tursiops truncatus* Montagu, 1821), striped dolphin (*Stenella coeruleoalba* Meyen, 1833), common dolphin (*Delphinus delphis* Linnaeus, 1758), sperm whale (*Physeter macrocephalus* Linnaeus, 1758), and *Globicephala* spp. while in recent years are occurring ever more frequent sightings (and strandings) of the sea turtle *Caretta caretta* Linnaeus, 1758.

In the sea in front of the National Park, it is also noted the presence of the following further species present in the annexes of the Habitats Directive (in general, some of the marine species listed in the "Report of the Italian fauna protected" written by the MATT, a document that lists protection status and health of every animal species and related legislation, are present along the coasts of Circeo):

Corallium rubrum Linnaeus, 1758. Red Coral, Habitats Directive, Annex V - reported presence at the site IT6040019

Pinna nobilis Linnaeus, 1758. Fin noble, Habitats Directive, Annex IV - Reported presence at the site IT6040020 and IT6000013

Scyllarides latus Latreille, 1802. Slipper Lobster, Habitats Directive, Annex V - Reported presence at the sites IT6040019 and IT6000013

Petromizon marinus Linnaeus, 1758. Sea lamprey, Habitats Directive, Annex II - Reported presence with a not very significant population at the site IT6040019

Aphanius fasciatus Valenciennes, 1821. Killfish, Habitats Directive, Annex II - Reported presence at the sites IT6040012 and IT6040013

The Lazio Region, within the programs Beachmed (Interreg) and ICZM (Integrated Coastal Zone Management), has produced two publications and analysis on the priorities for the conservation of coastal and marine natural values of the region (BEACHMED, 2004; DECOS, 2006; 2007). The coast of Circeo (particularly the area in front of Torre Astura, the area in front of the lakes and the one between Capo Circeo and Terracina) turns out to be one of the most interesting especially for the presence of *Posidonia*, which performs nursery function for fish and benthos. It should be recalled in this connection that the seagrass meadows are considered a priority habitat of interest at European level; in Italy, are further protected and secured since 2001 (Decree Law No. 93 of March 2001).

"La Sapienza" University of Rome has recently developed on behalf of the city of San Felice Circeo, a project for the knowledge and conservation of *Posidonia* meadows in the area of Circeo (Università degli studi di Roma "La Sapienza", Regione Lazio, 2008; Nascetti & Martino, 2009). According to this work, the current distribution of grasslands appears to be profoundly changed compared to what is reported in the works described above. Between Capo Portiere and Torre Astura there is a compact *Posidonia* meadow, with a relatively high density and settled on "matte", less compact due to the presence of large areas of erosion in slightly more depth and patches up to 31-32 m deep; some areas of this grassland show signs of an advanced state of regression while in others are present rock structures. *Posidonia* is present along the shoreline in front of Fogliano Lake, while it is absent between the headland and the mouth of Caprolace lake where it is present *Cymodocea nodosa* (Ucria) Asch., 1870 (Ardizzone & Belluscio, 1996; Diviacco et al., 2001)

The *Posidonia* meadow placed in front of the promontory of Circeo is what seems to be the least changed over the years, probably because localized further out than the others, and therefore less influenced by the contributions of continental waters, but also thanks to the presence of rocky substrates that probably have limited the activities of illegal trawling. In fact, the most western front of the Circeo promontory, has a meadow in good condition, settled on the rock in the middle part and on "matte" all around. A narrow zone with isolated bundles of *Posidonia* on dead "matte" is present in the vicinity of the bottom margin (Bouchette et al., 2008; Ardizzone et al., 2009; Nascetti & Martino, 2009). The central meadow, between Cape Circeo and Terracina, presents the most important regression of this stretch, especially evident with the retreat of the lower limit. This stretch of coastline was subject to heavy changes in the coastline due to the increased human pressure, with negative influences on both the quality of water on the grain size of the seabed. Most of the area is therefore occupied by a meadow extremely rarefied with large areas of dead "matte" (Bouchette et al., 2008; Ardizzone et al., 2009; Nascetti & Martin, 2009).

Summing up therefore the expeditious visual analysis of environmental emergencies and major areas of interest of the Latium coasts, we can identify two major areas of interest in offshore and sub-coast. Among the areas of greatest interest for the establishment of Marine Protected areas there is the offshore area in front of the Circeo; among the inshore areas the stretch between Capo Circeo and Terracina is particularly interesting for its fertility due to its geological features.

The Plan of the Park proposes a widening in the sea of the National Park that would include as well an extraordinary variety of plant and animal species, protecting and enhancing the features of the marine and coastal biodiversity, also and above all through environmental restoration measures. For these reasons could be implemented programs of study, monitoring and scientific research in the fields of natural science and environmental protection, with the aim of ensuring the systematic knowledge of the area, but also for the promotion of sustainable development of the environment, with particular emphasis on promoting traditional activities of local cultures, tourism and environmentally friendly use.

The areas involved by the proposal for extension of the CNP to the sea are largely already included in the Natura 2000 Network. With this proposal, according to the editors, the management of the offshore part of the "SPA IT6040015 Parco Nazionale del Circeo" and marine SCI that face the sea coast of the Park and of Zannone (SPAs "Pontine Islands") may be carried out in a unified manner by Park Authority that can ensure their preservation through various management interventions. This solution, also, would fully respond to international commitments in the European context for the

management of such sites, providing them with concrete organizational, and financial skills that would ensure the achievement of the objectives of the Birds and Habitats Directives. The proposal put forward at the time by Legambiente was, instead of setting up a real marine protected area, to include, rather, the entire complex of the seagrass meadows present both in the northern section of the coast and in the south (between San Felice and Terracina). Indeed, the marine area should not only encompass the entire SPA Circeo National Park, but we imagine that, facing if necessary with any reluctance of local municipalities, the park could also be a promoter of an extension of the area to the sea area surrounding the island of Zannone (therefore comprising part of the second SPA of the Park, the one concerning the archipelago of the Pontine Islands).

The ideal reference is to the "5 Terre National Park" where the synergy between marine protected area (institute aimed to the protection of marine environments) and the national park (which protects instead the ground part) has created an enviable model of resource management and, at the same time, of valorization of the tourist routes on which the socio-economic system of the district is largely based.

CONCLUSIONS

The coastal stretch in front of the National Park of Circeo between Capo Circeo and Terracina and between Astura and Capo Circeo, is one of the coastal areas of most interest throughout the region of Lazio in consideration of the presence of important *Posidonia oceanica* meadows. The importance of submerged marine vegetation, especially of the systems of marine phanerogams, was now scientifically recognized as crucial for their contribution to the maintenance of infralittoral ecosystems. This aspect suggests a priority in the preservation of the natural values of the coastal and marine areas.

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The continental molluscs from Mount Circeo (Latium, Italy)

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ABSTRACT   This paper is the second step in a process that aims to asses biodiversity of land and freshwater molluscs fauna of Mount Circeo (Latium, Italy). Forty species of land and freshwater molluscs are listed, three more than in the previous work. A species of *Oxychilus* Fitzinger, 1833 and two species of *Limax* Linnaeus, 1758 remain undetermined, to date. The presence of *Pleurodiscus balmei balmei* (Potiez et Michaud, 1838) and *Siciliaria gibbula honii* (O. Boettger, 1879) are confirmed and this is the known northern limit of their distribution areas in Italy. Moreover, the presence of some species of biogeographical interest has allowed us to formulate some hypotheses on the origin of this fauna, in the light of the most recent theories on the formation of the Italian peninsula.

KEY WORDS   Continental molluscs; Mount Circeo; checklist.

INTRODUCTION

The 2nd Malacological Pontine Conference of 2008, gave us the opportunity to presented a first contribution on the biodiversity of land molluscs of Mount Circeo (Hallgass & Vannozzi, 2008). The research carried out in this territory, which progressed in the recent last years, allowed us to update our knowledge of this fauna which is reported in the following.

Study area

Mount Circeo is a promontory composed mostly of marl and sandstone from the Paleogene and of limestone from the lower Early Jurassic, which is different from that constituting the nighbouring Ausoni Mountains (Fig. 1). The shape of the promontory is elongated in east-west direction with a length of about 6 km, and a maximum height of 541 m above sea level (reached at the "Pizzo di Circe"); other important heights are the "Semaforo" (412 m) and the "Le Crocette" (352 m).

The geographical position of the promontory contributes to create some sub-environments in relation to their different exposure:

• "Quarto Freddo" with northern exposure.

• "Quarto Temperato" with western exposure; it is a transition from the south side to the north side, therefore it has no particular interest.

• "Quarto Caldo" with southern exposure.

• "Quarto Comunale" with eastern exposure; it is anthropized and altered and therefore of little naturalistic interest.

Our interest was, therefore, focused on the two slopes, the northern and the southern ones. The vegetation in Mount Circeo is typically Mediterranean but is very different by structure and composition in the two mains slopes.

QUARTO FREDDO. The vegetation on the northern slope of the mountain is made up of a dense forest of tall trees dominated by holm oak. At the baseline, however, there are scattered examples of Italian oak, oak, and hornbeam, which represent the penetration of the neighboring plainforest.

Other trees or shrubs species well represented are: mock privet, ash, arbutus, heather and buck thorn. Towards the plain, however, the beautiful "Sughereta di Mezzomonte", whose underwood is characterized by fallen branches of which soon remains only the thick bark that provides a shelters for many species of molluscs (Figs. 3, 6). At about 200 meters above the sea level, we observed there forestation of conifers that made the canopy of the forest higher; the oaks adapted and have a very slender truncks while the cork oaks were not able to reach the canopy and are found as skeletons in the underwood. At the top of the mountain on both lopes there is the limestone exposed, which is the exclusive habitat of strictly calciphilous species.

QUARTO CALDO. In the medium and high area of the mountain, the vegetation is very compact and consists of high and low maquis species dominated by arborescent layer of oak with plenty of ash, arbutus, mastic, heather and broom. The low maquis is prevalent mostly in the lower part of the promontory and is dominated by mastic, phillyrea, myrtle, and holm oak which, in addition, shows a bushy shape. Very interesting is the presence of several specimens of the dwarf palm (*Chamaerops humilis* L.), the only spontaneous palm in Italy. On all the rock sand cliffs overlooking the sea, we found a discontinuous grouping characterized by lavender pillows placed near to the ground, sea fennel and compact clumps of weeds beaches, sometimes associated to the enula. In more humid valley sholm returns to be dominant in the tree shape.

On the promontory several species of molluscs from different neighboring environments can be found. The thermophilic species can reach the promontory from the adjacent dune and colonize hot-arid environments. From the adjacent plain forest are the species characteristic of a moist environment; however, much more interesting are the strictly calciophilous species that could be the remains of the old fauna of the promontory. For some species, we cannot rule out an anthropogenic input.

MATERIAL AND METHODS

The research of terrestrial molluscs was made by manual sampling for most species. The list of localities under consideration is shown in Table 1.

Collected samples were deposited in the malacological collection of the "Museo del Mare e della Costa" of Sabaudia. Some very small species, isolated
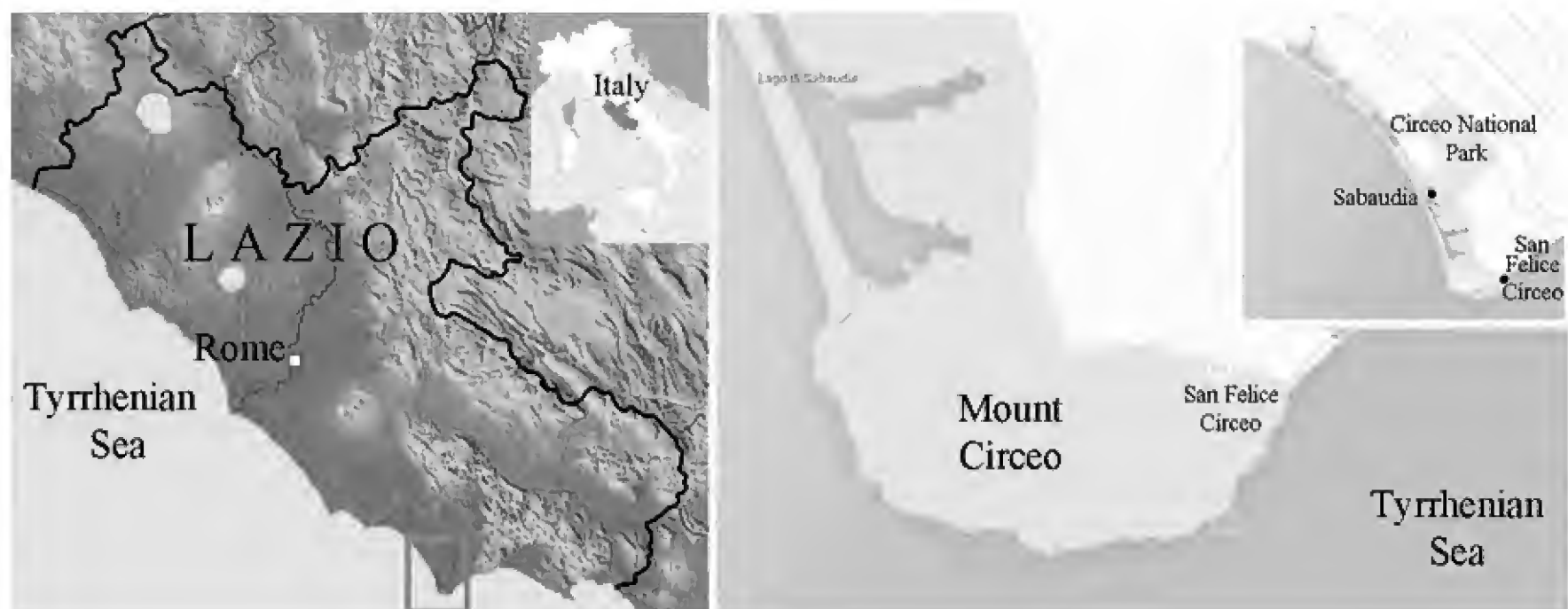

Figure 1. Study area: Mount Circeo, Latium, Italy.

locality ID	locality	slope	coordinates	altitude a.s.l. (m)	type of environments
1	From the road to "le Crocette" at the beginning of the trail to "la Guardia di Orlando"	Quarto freddo	41°14'15"N 13°04'57"E	192	Ilex (Holly) trees
2	Top trail between "il Semaforo" and " il Fortino Rosso"	Quarto freddo	41°13'55"N 13°04'09"E	352	High maquis
3	Source of "Mezzomonte"	Quarto freddo	41°14'23"N 13°04'13"E	45	Dense woods of Ilex (Holly) and cork oak trees
4	"La Cava"	Quarto freddo	41°14'36"N 13°04'55"E	42	drystony ground and limestone wall exposed
5	Beginning of trail 1 (Torre Paola)	Quarto freddo	41°14'48"N 13°02'23"E	30	Holly trees
6	Crossroads between"del Faro" road and "del Sole" road	Quarto caldo	41°13'25"N 13°03'59"E	49	limestone wall exposed and low maquis
7	On the walls of the houses of "S. Felice al Circeo"	Quarto comunale	41°13'60"N 13°05'16"E	98	ruderal

Table 1. List of sampled localities of Mount Circeo (Latium, Italy).

species	1	2	3	4	5	6	7	B	figs.
Platyla cf. *microspira* (Pini, 1884)								x	
Pomatias elegans (O.F. Müller, 1774)	vvv	vvv	vv	vv		vv		x	2, 12
Pseudamnicola moussonii (Calcara, 1841)								x	
Islamia pusilla (Piersanti, 1952)								x	
Galba truncatula (O.F. Muller, 1774)								x	
Carychium tridentatum (Risso, 1826)								x	
Rupestrella philippii (Cantraine, 1840)						vvv			13
Granopupa granum (Draparnaud, 1801)						c			14
Acanthinula aculeata (O.F. Müller, 1774)								x	
Lauria cylindracea (Da Costa, 1778)				vvl				x	15
Pleurodiscus balmei (Potiez et Michaud, 1838)						cc			18

Table 2 (continued). List of continental molluscs found in Mount Circeo (Latium, Italy) in the seven localities reported in Table 1. Additional species collected by M. Bodon (pers. comm.) are listed in coloumn B. Abbreviations. v: living specimen; c: empty shell. Single specimen: +; some specimens (2-4): + +; several specimens: + + +. In the case of many living specimens, data on empty shells have been omitted. 1 in wall; 2 ilex wood; 3 juv.; 4 on road cut rocks.

species	1	2	3	4	5	6	7	B	figs.
Chondrula tridens (O.F. Müller, 1774)						cc			17
Punctum pygmaeum (Draparnaud, 1801)								x	
Discus rotundatus (O.F. Müller, 1774)	vvv	vvv	vvv	vv	vv			x	3
Vitrea contracta (Westerlund, 1871)			c					x	16
Oxychilus sp.	cc		v-cc	cc		cc2		x	19
Daudebardia rufa maravignae (Pirajno, 1840)								x	
Tandonia sowerbyi (Férussac, 1823)			vv3						4
Limax sp. 1	vv3		vv		vv				5
Limax sp. 2			vv						6
Cecilioides acicula (O.F. Müller, 1774)								x	
Rumina decollata (Linnaeus, 1758)		cc		cc		cc			28
Leucostigma candidescens (Rossmässler, 1835)	vvv4	vvv	vvv	vvv		vvv4		x	8, 22
Cochlodina incisa (Küster, 1876)	vv								20, 21
Siciliaria paestana (Philippi, 1836)	vvv	vvv	vvv	vv	vvv	cc2		x	9,25,26
Siciliaria gibbula honii (O. Boettger 1879)					vv				27
Papillifera bidens (Linnaeus, 1758)				vvv					23, 24
Xerotricha apicina (Lamarck, 1822)				v-ccc					29
Xerotricha conspurcata (Draparnaud, 1801)						vv-ccc			31
Hygromia cinctella (Draparnaud, 1801)			c						35
Cernuella cisalpina (Rossmässler, 1837)				vv-ccc		c			34
Trochoidea trochoides (Poiret, 1789)				vvv					30
Cochlicella acuta (O.F. Müller, 1774)				vvv					33
Cochlicella conoidea (Draparnaud, 1801)				vv				x	32
Chilostoma planospira (Lamarck, 1822)	v		vv					x	10,36,37
Marmorana muralis (O.F. Müller, 1774)							cc		38
Marmorana fuscolabiata circeja (Kobelt, 1903)	vv-cc4					vv-cc		x	11, 39
Eobania vermiculata (O.F. Müller, 1774)		cc		v-ccc		cc		x	
Cantareus apertus (Born, 1778)				cc					
Cantareus aspersus (O.F. Müller, 1774)				cc					

Table 2. List of continental molluscs found in Mount Circeo (Latium, Italy) in the seven localities reported in Table 1. Additional species collected by M. Bodon (pers. comm.) are listed in coloumn B. Abbreviations. v: living specimen; c: empty shell. Single specimen: +; some specimens (2-4): + +; several specimens: + + +. In the case of many living specimens, data on empty shells have been omitted. 1 in wall; 2 ilex wood; 3 juv.; 4 on road cut rocks.
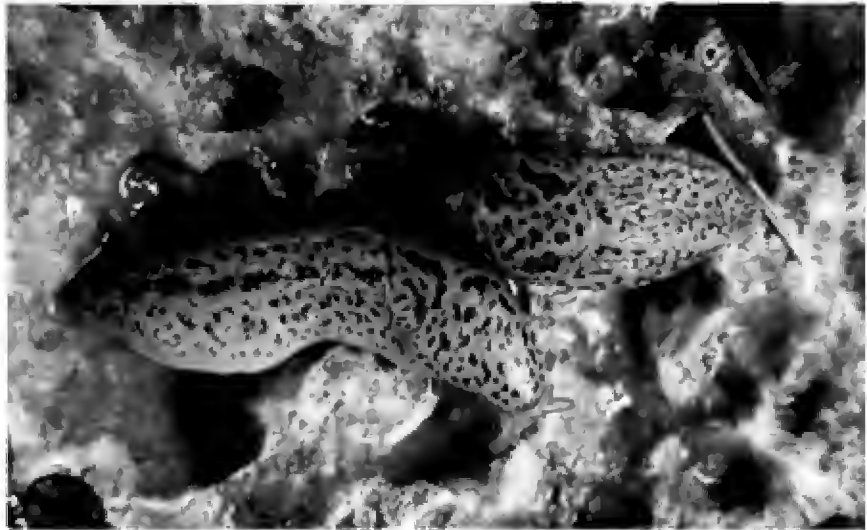
Figs. 2–9. Land snails from Mount Circeo. Fig. 2. *Pomatias elegans.* Fig. 3. *Discus rotundatus.* Fig. 4. *Tandonia sowerbyi.* Fig. 5. *Limax* sp. 1. Fig. 6. *Limax* sp. 2. Fig. 7. *Limax maximus* from Terracina. Fig. 8. *Leucostigma candidescens.* Fig. 9. *Siciliaria paestana.*

by sieving litter and soil, and some freshwater species found in the source Coppelia in San Felice Circeo, were collected by M. Bodon and have been added to the list of species found in this study (Table 2). It was not possible to carry out surveys of freshwater species in the source "Mezzomonte", the main source of the promontory, which provides water to the town of San Felice Circeo and now completely captured and inaccessible.

For the systematic nomenclature we referred mainly to the Checklist of the species of the Italian Fauna (Bodon et al., 1995; Manganelli et al., 1995); for the supra-generic systematic see the "Classification and nomenclator of gastropod families" (Bouchet & Rocroi, 2005).

All specimens illustrated are from the Mount Circeo, unless otherwise stated.

RESULTS

At present, 40 species of continental molluscs are known from Mount Circeo, the most interesting of which will be briefly commented on below. The full list is shown in Table 2.

Taxonomic list

Familia ACICULIDAE

Platyla cf. *microspira* (Pini, 1884)

This species is morphologically referable to *P.*

microspira and is also known from the rear Ausoni Mountains (Bodon & Cianfanelli, 2008). There still remains, however, uncertainty concerning the identity of the species, taken into account the geographic isolation from the typical populations of Lombardy and Liguria.

Familia CHONDRINIDAE

Rupestrella philippii (Cantraine, 1840)

Two empty shells of this small species (Fig. 13) were found among the rocks of a road cut along with *Granopupa granum* (Draparnaud, 1801). The association of these two species has already been documented by Giusti (1970) for the Pianosa Island. It would be extremely useful to study these two small species from a genetic stand point, being almost impossible to understand the relationships among their populations either by anatomical or morphometric analysis.

Granopupa granum (Draparnaud, 1801)

This small species (Fig. 14) is widespread in Italy and in Holomediterranean-Macaronesian-Turanian region, albeit discontinuously, since it is closely associated with a limestone substrate. It is common in Mount Circeo and the shell is morphologically little variable.

Familia PLEURODISCIDAE

10

11

Figs. 10, 11. Land snails from Mount Circeo. Fig. 10. *Chilostoma planospira.* Fig. 11. *Marmorana fuscolabiata circeja.*

Pleurodiscus balmei balmei (Potiez et Michaud, 1838)

Only some empty shells of this species were found (Fig. 18); however, one of them was a very fresh shell, and we believe that this species actually lives in Mount Circeo. This is the most northern record of the species in the Italian peninsula. Recently it has also been reported for Apulia (Ferreri et al., 2005; Bassi, 2007). Instead, it is well known for southern Calabria, Sicily and Malta (Giusti et al., 1995). The population of Mount Circeo could be a relict population, but we cannot exlude a passive introduction by man, as *P. balmei* is frequent in ruderal habitats, gardens etc. (Kerney & Cameron, 1979).

Familia DISCIDAE

Discus rotundatus (O.F. Müller, 1774)

A very common species and widely distributed throughout Italy and Europe, *D. rotundatus* is characteristic of the underbrush (Fig. 3). The diameter of the shell does not exceed 7 mm. In the forests of the "Quarto Freddo" the thick bark of fallen branches of cork oaks creates an ideal habitat for this small gastropod.

Familia PRISTILOMATIDAE

Vitrea contracta (Westerlund, 1871)

It has been found only a shell of this European widespread species (Fig. 16). In Italy it is found at low altitudes along the coast, while at higher altitudes it is replaced by other congeneric species (Giusti et al., 1985).

Familia OXYCHILIDAE

Oxychilus sp.

One living specimen and some shells of this species were found (Fig. 19). Although it is morphologically similar to a small form of *O. draparnaudi* (Beck, 1837), it will be necessary to investigate anatomical features in detail to determine its specific identity. As already pointed out by Manganelli & Giusti (2001), species of *Oxychilus* Fitzinger, 1833 with well characterized genitalia may show identical shells.

Familia MILACIDAE

Tandonia sowerbyi (Férussac, 1823)

The species of *Tandonia* Lessona et Pollonera, 1882 genus are necrophagous and carnivorous molluscs. Only some juveniles were observed in mount Circeo. Externally it is distinguished from congeners by the dorsal hull orange and the clear sole (Fig. 4). It is widely spread throughout Italy, probably dispersed by man.

Familia LIMACIDAE

Limax sp. 1

This species (Fig. 5) is of medium size for the genus, about 10–12 cm long; it is characterized by colour, ocher-yellow, with a lighter uniform sole, colour similar to *Limax bivonae* Lessona et Pollonera,1882, reported for north-eastern Sicily (Reitano et al., 2007). It was sampled at different localities of the promontory.

Limax sp. 2

Same size as the previous one, with darker color and a pattern of small irregular spots limited to the clypeus, looking as a variation of *L. maximus* Linnaeus, 1758. Only two specimens were found in the cork trees of Mezzomonte (Fig. 6). It is currently not possible to determine whether *Limax* sp. 1 and *Limax* sp. 2 belong to a single or two distinct species. For the external morphology, both species are attributable to the group of *L. maximus*. However a few miles from these findings, out of the promontory, towards Terracina, we observed *L. maximus* specimens with the characteristic spotted livery (Fig. 7).
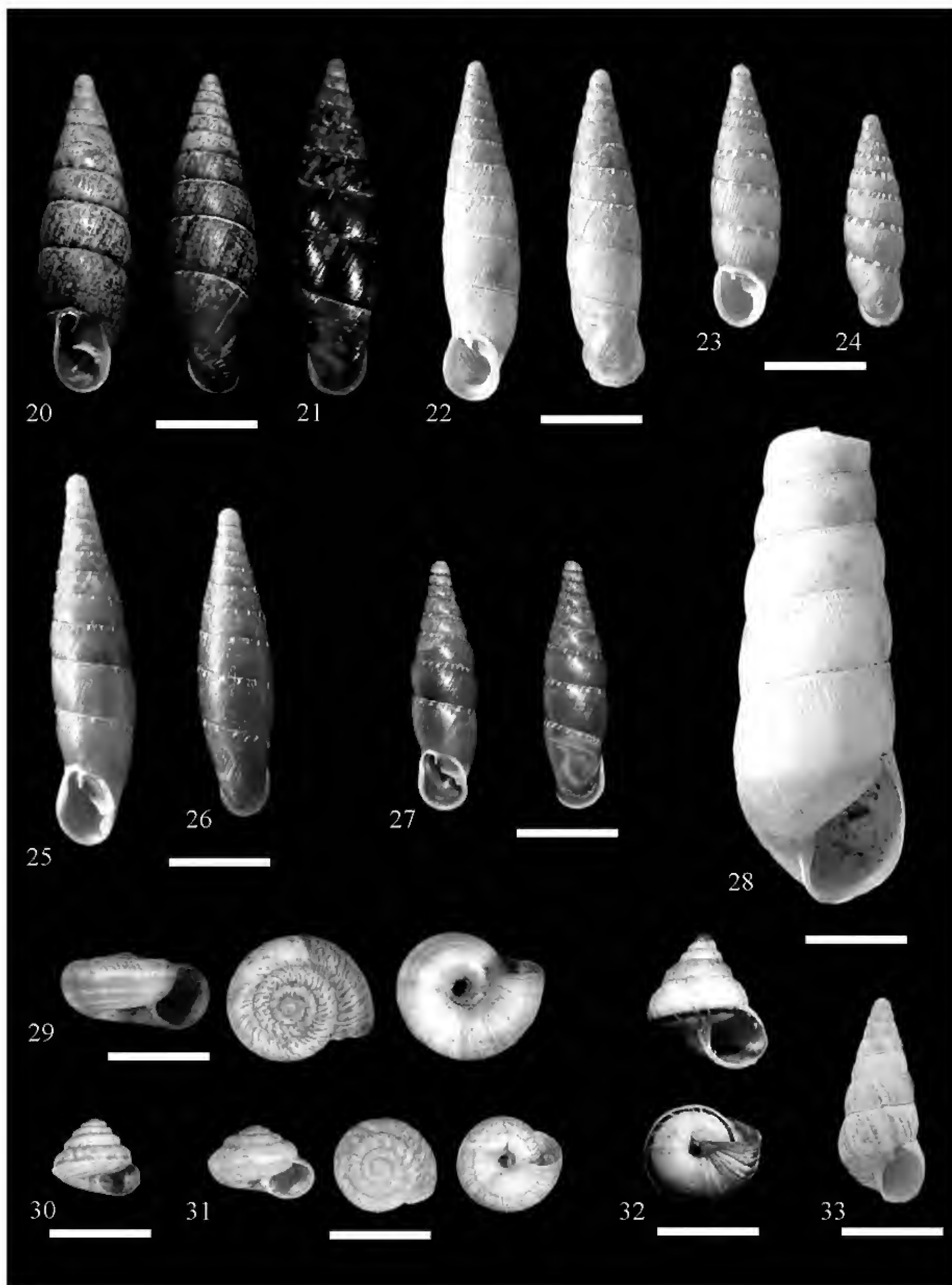
Familia CLAUSILIIDAE

### *Leucostigma candidescens* (Rossmässler, 1835)

This species (Figs. 8, 22) is strictly calciophilous
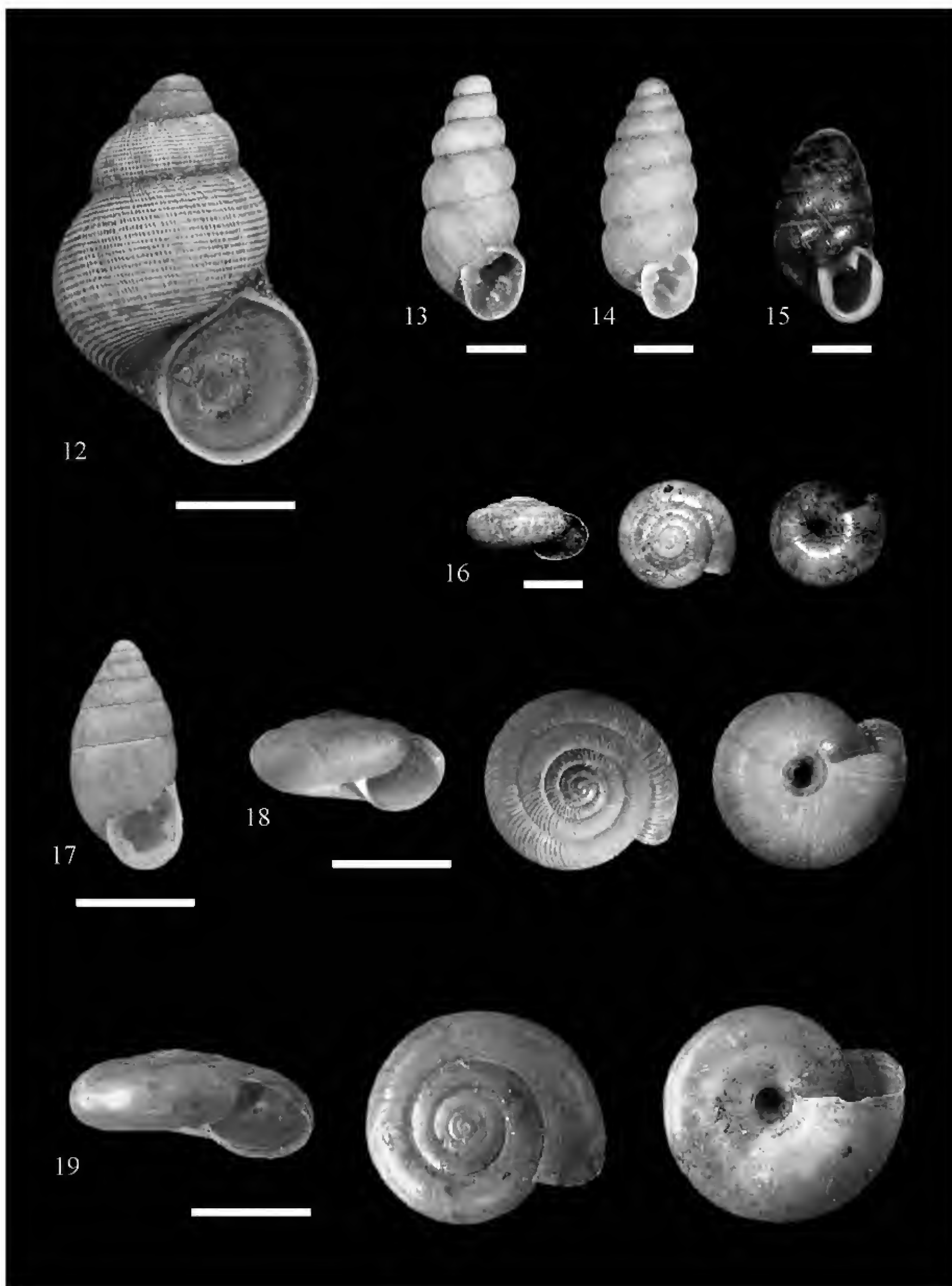
Figs. 12–19. Land shells from Mount Circeo. Fig. 12. *Pomatias elegans*. Fig. 13. *Rupestrella philippii*. Fig. 14. *Granopupa granum*. Fig. 15. *Lauria cylindracea*. Fig. 16. *Vitrea contracta*. Fig. 17. *Chondrula tridens*. Fig. 18. *Pleurodiscus balmei*. Fig. 19. *Oxychilus* sp.

Figs. 20–33. Land shells from Mount Circeo. Fig. 20, 21. *Cochlodina incisa.* Fig. 22. *Leucostigma candidescens.* Figs. 23, 24. *Papillifera bidens.* Figs. 25, 26. *Siciliaria paestana.* Fig. 27. *S. gibbula honii.* Fig. 28. *Rumina decollata.* Fig. 29. *Xerotricha apicina.* Fig. 30. *Trochoidea trochoides.* Fig. 31. *X. conspurcata.* Fig. 32. *Cochlicella conoidea.* Fig. 33. *C. acuta*
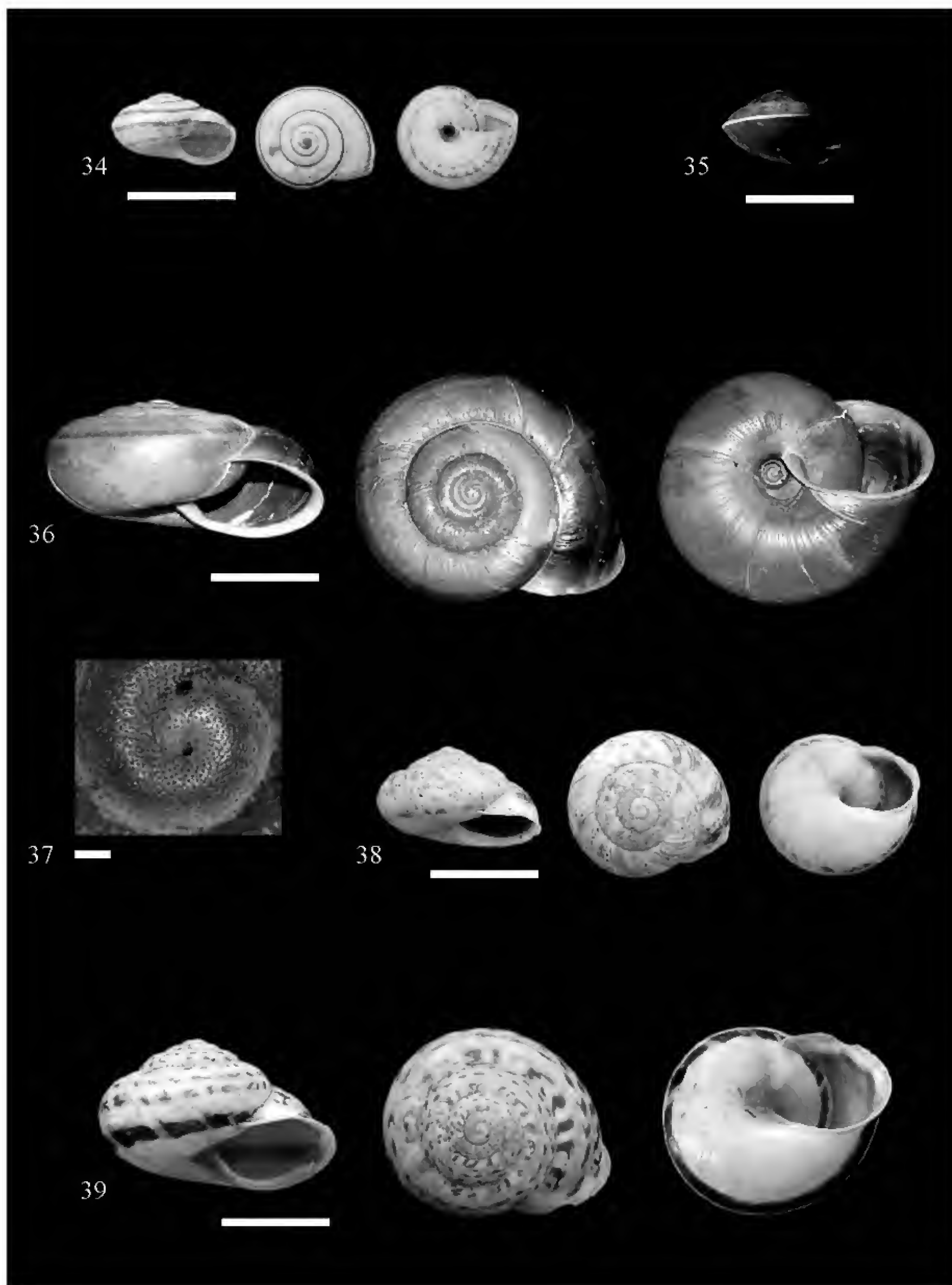
Figs. 34–39. Land shells from Mount Circeo. Fig. 34. *Cernuella cisalpina.* Fig. 35. *Hygromia cinctella.* Fig. 36. *Chilostoma planospira.* Fig. 37. *C. planospira:* protoconch with numerous tubercles. Fig. 38. *Marmorana muralis.* Fig. 39. *Marmorana fuscolabiata circeja.*

and is distributed in the Italian peninsula (Umbria, Latium, Abruzzo and Campania). It is characteristic of exposed walls however, it can also be found in the woods, always on the rocky walls. The populations of Mount Circeo, not particularly abundant, are of medium-small size for the species (h: 12–17 mm). It is morphologically similar to the southern morphs of the species, i.e. whitish with small papillae, and almost indistinguishable from the forms present on Ausoni Mountains at Terracina. In the nearby Lepini Mountains is dominant *Leucostigma leucostigma* with purplish-brown shell and papillae more evident. In Latium there are populations of giant specimens, that exceed 22 mm.

Cochlodina incisa (Küster, 1876)

Species widely distributed in Italian peninsula at low altitudes. Above 1000 m it is replaced by *C. laminata* (Montagu, 1803), a species widespread all over Europe. In the contact areas the two species are found in sympatry. *C. incisa* from Mount Circeo (Figs. 20, 21) compared to the Apennine populations, shows a more obese shell, sometimes with numerous intermediate palatal plicae. As far as converns its anatomical features, no differences were observed. *C. incisa* was found, with the same character, even in the littoral ilex trees wood of Macchiagrande (Rome).

This species is closely related to *C. kuesteri* (Rossmässler, 1836) and *C. meisneriana* (Shuttleworth, 1843) which are found in Sardinia and Corsica, respectively.

Siciliaria paestana (Philippi, 1836)

A common species (Figs. 9, 25, 26) in the coastal area of the Tyrrhenian coast, in alluvial plain between the ancient Pliocene coast line and the present coast, from low lands behind the dunes to the inner areas with low vegetation, never in very humid environments. The southern boundary for this species is Paestum, its locus typicus. In the south and east part of the species range (Campania and Basilicata), there are some forms of uncertain taxonomic status.

Siciliaria gibbula honii (O. Boettger, 1879)

Poorly known species (Fig. 27), widespread from the Vesuvian area to southern Latium. It is generally uncommon, abundant only on the Ventotene island where it is the dominant species.

Nordisieck (2013) considers doubtful the sub-specific relationship with *S. gibbula*. Further research is needed to clarify the relationship of *S. gibbula honii* with some form of *S. gibbula* in Calabria, the Aeolian Islands and with *Siciliaria vulcanica* (Paulucci, 1878) from Mount Etna.

Papillifera bidens (Linnaeus, 1758)

Synonyms: *Papillifera papillaris* (O.F. Müller, 1774). It is one of the species of Clausiliidae most widely dispersed by man. It is common on old walls. In Italy, *P. bidens* lives in natural habitats only in Apulia, Basilicata, Calabria, Sicily and Sardinia. Within the Mount Circeo it was found in the locality known as "La Cava" and on the walls of the town of San Felice (Figs. 23, 24) with *Marmorana muralis* (O.F. Müller, 1774).

Familia HYGROMIIDAE

Xerotricha apicina (Lamarck, 1822)

Species common (Fig. 29) in uncultivated lands to the low lands behind the dunes. It is widespread in Italy up to the Mediterranean coast of France. The shell of the juvenile specimens has hairs on the periostracum that do not persist in the adult.

Xerotricha conspurcata (Draparnaud, 1801)

This species is similar to *X. apicina*, however, is smaller and with hairs of periostracum persisting in adults (Fig. 31). It prefers areas less exposed respect to the congener. Widespread throughout Italy.

Hygromia cinctella (Draparnaud, 1801)

Species common in humid environments of the Italian peninsula and Sicily. In the Mount Circeo (Fig. 35) as found only one shell, not very fresh, in the cork oak of Mezzomonte.

Familia HELICIDAE

Chilostoma planospira (Lamarck, 1822)

This species lives under brushes among the rocks (Fig. 36). Anatomical examination of a living specimen revealed an asymmetry in the morphology of the two mucous glands, one being simple and the other one bifid. This feature is not mentioned by any authors and could fall within the variability of the species. The protoconch is adorned with numerous tubercles (Fig. 37).

Marmorana muralis (O.F. Müller, 1774)

This species has a Sicilian distribution, but it has been dispersed by man in many site in the western Mediterranean area. In the Italian peninsula it is known only in anthropic environments, with the exception of two localities in Umbria and Calabria. In Sicily it is rather widespread either in natural or ruderal environments. In Mount Circeo (Figs. 10, 38) it was found on the walls of the town of San Felice with *Papillifera bidens*.

Marmorana fuscolabiata circeja (Kobelt, 1903)

Marmorana fuscolabiata (Rossmäsler, 1842) is widespread in the Southern Apennines. Geographical isolation of the population of Mount Circeo (Figs. 11, 39) and the relative genetic distance compared to other neighboring population it seems to justify the use of the rank of subspecies (Oliverio et al., 1992). In recent years, probably because of the drought, there has been a substantial decrease in the number of individuals.

DISCUSSION AND CONCLUSIONS

Mount Circeo has long been an island; indeed a sea bottom that does not exceed 300 m below the sea level joins it to the Pontine Islands. This is a group of volcanic islands, but still retains, in the island of Zannone, a portion of the limestones that possibly were part of a bigger platform.

The theory of Alvarez et al. (1974) explains the formation of Italy and of the western Mediterranean by the counterclockwise rotation of the Sardo-Corsican plate. Originally joined to the European plate in correspondence of Provence, during its rotational movement eastward, fragments detached to

form Balearic Islands, Corsica and Sardinia. Of great importance is the Calabro-Peloritan micro-plate that detached from the whole Sardo-Corsican complex giving rise to the Tyrrhenian Sea. This theory has allowed us to explain the fragmented distribution of species with very low dispersal ability, including *Papillifera solida* and the species of the genus *Solatopupa* Pilsbry, 1917 as well as the close relationship that occurs between *Cochlodina kuesteri* and *C. incisa* (Giusti, 1976; Ketmaier et al., 2006).

The distribution of *Cochlodina* Férussac, 1821 species may be explained by the fragmentation of the Alps occurred during the Oligocene. It is possible that the distribution area of one species of *Cochlodina* living within the entire Alpine region was fragmented and that the various isolated populations differentiated in different species over time. In fact, we note that the center of diffusion of the genus *Cochlodina* is the Alpine region, where there are a dozen species, occurring – in addition to the Alps and the Italian mainland – also in Corsica with *C. meisneriana*, in Sardinia with *C. kuesteri*, and in Algeria (Kabilya) with *C. bavayana* Hagenmüller, 1884 (Nordsieck, 1969), all fragments of the original Alps, as well as it could have occurred in the micro-plates that huddled to form the Apennines.

With the change of latitude the "Tyrrhenian" *Cochlodina* adapted to warmer climates. It is therefore possible that the populations of *C. laminata* that live at high altitudes in the Apennines are a relict fauna that came down from the north in the colder periods and, subsequently, *C. incisa*, coming from the west, colonized habitats at lower altitudes. However, genetic studies are needed to test this hypothesis.

However, although the theory of Alvarez et al. (1974) is now universally accepted, it leaves a large margin of uncertainty as to how and when the various plates did move. Duermeijer et al. (1997) believe that the separation between the Sardo-Corsican complex and the Calabro-Peloritan microplate occurred between 8.6 and 7.8 Mya, with the opening of the Tyrrhenian Sea. The study on enzyme polymorphisms on the genus *Marmorana (Ambigua)* (Oliverio et al., 1992) partly confirms and partly is in contrast with this opinion. In fact, these times are well suited for the separation between the *Tyrrheniberus ridens* (Martens, 1884) from Sardinia and the *Marmorana signata* group (Férussac, 1821), but do not justify neither the much lower distance between *Tyrrheniberus* and the *Marmorana fuscolabiata*

group nor the proximity of this latter to *Marmorana saxetana* (Paulucci, 1886) occurring in the Argentario. The genetic distance between *Tyrrheniberus* and these latter two species would suggest a separation occurred between 4 and 5 Mya.

A model that could justify these inconsistencies would require the separation, at different times, of the various plates travelling separately and subsequently fused to form the current Italian peninsula. The Calabro-Peloritan microplate at the time of separation from the whole Sardo-Corsican complex might appear as an island very elongated in north-south direction that, for a certain time, traveled as a whole block.

During the movement from north-west to south-east this microplate broke in several pieces, some of which moved away to form the Argentario and the calcareous parts of the Tuscan Archipelago, respectively; this event could might have occurred between 3.5 and 3 Mya.

In more recent times there was a sliding movement of the plate to the south (Van Dijk & Scheepers, 1995) that might have caused a new division of the plate from which it broke away the part that we find today as Mount Circeo and the limestone debris of Zannone Island. This event may be dated between 1 and 0.7 Ma. This model could explain the presence of *Marmorana fuscolabiata* on Mount Circeo, the relatively close genetic distance between *M. fuscolabiata* and *M. saxetana* and the greater genetic distance that separates these two species from *M. signata* of Ausoni Mountains, less than 15 km far from Mount Circeo, and could also explain other biogeographic mysteries such as the presence of *Pegea carnea* (Risso, 1826) in Pantelleria Island (Sparacio, 1997), the Aeolian Islands and the Tuscan Archipelago and the presence of *Pleurodiscus balmei* at Mount Circeo. Only an additional contribution of genetic data related to groups and species strictly calciphilous with very low dispersal abilities may corroborate or refuse this hypothesis.

ACKNOWLEDGEMENTS

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Urban ecology: comparison of the effectiveness of five traps commonly used to study the biodiversity of flying insects

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ABSTRACT   In this paper, we compare five different types of traps currently used in biodiversity studies to collect flying insects. Our aim is to evaluate the potentials and the limits of these traps in the assessment of insect biodiversity. Hence, we compared the diversity of insects caught by a malaise trap, a yellow pan trap, a blue pan trap, a suction trap and a light trap in six different locations in Brussels. We showed that these traps caught nearly only insects: more than 98.3% of all collected organisms were insects. Only the blue pan trap caught, in higher proportions, other arthropods such as isopods or spiders. The Malaise trap was generally the most effective trap capturing the majority of Homoptera, Heteroptera, Psocoptera, Diptera, Trichoptera and Hymenoptera. The yellow pan trap was often the second most effective trap particularly for Hymenoptera, Diptera and Homoptera. Without surprise, the light trap caught nearly all Lepidoptera (Heterocera). Some combinations of two different traps were very effective. However, none of these combinations were the most effective for all families of insects. Moreover, the combination of the two most effective traps (Malaise and yellow pan traps) was not the best combination. We discuss about the effectiveness of traps and the usefulness of their association. Finally, we raise the particular case of urban environment which needs the use of discreet traps.

KEY WORDS   Malaise trap; pan traps; suction trap; light trap; complementary traps; biodiversity.

Received 04.02.2014; accepted 23.04.2014; printed 30.06.2014

INTRODUCTION

Since the Earth summit in 1992, the conservation of nature has taken more and more importance in the world. The creation of an international day for biological diversity is a symbolic fact of the communication of the problem of the loss of biodiversity. At the same time, many actions were developed to fend off this trend. For example, the involvement to halt the loss of biodiversity by 2010 shows that more people feel concerned about the conservation of natural heritage (Delbaere, 2004; EEA, 2007).

However, it is often difficult to explain why biodiversity is important and why we should be bothered with conserving it. Moreover, conservation of biodiversity creates constraints for people who can not see immediate outcomes. Some new political decisions, aimed decreasing the discrepancy between the knowledge of scientists and general understanding of people, have been introduced (in France, scientific foundation for biodiversity was launched in 2008). It can be very difficult for a non-specialist to understand that in order to make a success of the

big challenge to halt the loss of biodiversity by 2010, the first step of these studies includes the requirement to kill organisms. Indeed, to analyse biodiversity, scientists have to make inventories of organisms in each locality. For numerous classes of small animals (for example insects), the making of such inventories implies that organisms have to be killed. During such research, the killing of animals is generally not specific and is indiscriminate thus there is a risk that rare species may be destroyed. Moreover, the traps designed to kill insects could potentially kill other animals (Pendola & New, 2007). Fortunately, many species can be inventoried without killing (generally the vertebrates, and some insects like Orthoptera). However for the majority of insects, death is unavoidable during capture. Besides, insects are often used in ecological studies as indicators species of biodiversity (Duelli et al., 1999; Duelli & Obrist, 2003; EEA, 2007), of fragmentation or urbanisation of an environment (Kremen et al., 1993, Abensperg-Traun et al., 1996; Bolger et al., 2000; Nelson, 2007). Consequently, biodiversity studies are often confronted by this paradox: to study biodiversity in order to improve our knowledge, and thus to increase our abilities to protect and conserve it, specimens have to be killed. In the extension of this paradox, some papers asked for the development of ecological ethics or raised interesting ideas about the ethics of killing organisms for the purposes of scientific studies (Lockwood, 1987; Lockwood, 1988; Minteer & Collins, 2005a; Minteer & Collins, 2005b).

Most studies concerning biodiversity need not collect every species in a location. Indeed, researchers have developed several methods and strategies. In this respect, different methods are available to estimate species richness in an area: the use of a correlation with determination level (Andersen, 1995; Oliver & Beattie, 1996a; Oliver & Beattie, 1996b; Andersen, 1997), the use of indicator species (Rodriguez et al., 1998 but see McIntyre et al., 2001; Kotze & Samways, 1999; Osborn et al., 1999), the use of statistical methods to infer the species richness from a sample (Colwell & Coddington, 1994). However, if the aim is to take inventory of animals in a location then the observation and the capture of at least one organism of each species is necessary. Several ways are possible to limit the death of insects. One of the ways is the use of effective traps to limit the sampling frequencies. In

this respect, some studies were carried out to evaluate the best trap design (Abensperg-Traun & Steven, 1995; Wang et al., 2001; Koivula et al., 2003; Pendola & New, 2007), the best number of necessary traps (Brose, 2002) or to compare effectiveness and the complementarities of different traps (Lewis, 1959; Obrist & Duelli, 1996; Duelli et al., 1999; Agosti et al., 2000; Campbell & Hanula, 2007). However, many of these studies focused on one or two species and were not dedicated to global biodiversity estimation (Brunner et al., 2007; Hossain et al., 2007; Hardwick & Harens, 2007; Magina et al., 2007; Wu et al., 2007; Blackmer et al., 2008). The studies aiming at studying trapping methods in biodiversity evaluation are marginal compared to the literature about biodiversity generally. In this paper, we seek to compare 5 traps commonly used in biodiversity studies to collect flying insects in order to evaluate their potential and their limits in the assessment of insect biodiversity. In this paper, a trap was considered as most effective when it captures more number of insects or number of families of insects. Hence, it is attempted to define the effectiveness of a trap as a function of their captures (abundance of insects) and not from an economic point of view.

MATERIAL AND METHODS

The locations of trapping

The study was carried out in 6 locations in Brussels. These sites were chosen according to their biological potential, it means their assumed probability to have a high biodiversity. Three categories of biological potential were defined as a function of the urban location of the site (if it is at the urban periphery or not), the management of the site (strong human impact or not) and the previous estimation and information given to us by the IBGE (Institut Bruxellois pour la Gestion de l'Environnement - the Brussels institute for the environmental management). Consequently, 2 locations were supposed to have a great biological potential and hence a high biodiversity (the Massart botanic Garden, and the Zavelenberg area), 2 locations, a mean biological potential (the Tenbosch park and an abandoned private garden at Simonis street) and 2 locations, a poor biological potential (the highly maintained

garden of the Palais des academies and a very urban private garden at Berceau street).

It is apparent that these sites are not directly comparable. Indeed, the private gardens are very small compared with the urban parks. However, the aim of this study was to compare the effectiveness of different kinds of traps and not to compare biodiversity of different locations. Moreover, the use of different urban green spaces should allow the study to conclude about a potential generalisation of the results.

Traps

In each site studied, 5 different traps, designed to preferentially capture flying insects, were utilised and compared:

- A suction trap was used (Fig. 1) for 30 minutes in daylight (unfortunately, due to the noise of such a trap, we were not able to use it during the night). This trap consisted of a leaf blower/vacuum (PART-NER-BV24 / nominal air flow = $0.142m^3/s$) directed toward the sky. A 2.5 metre high pipe (12 cm diameter) was adapted in order to increase the height of capture. A funnel with a collecting bottle was inserted into the pipe to allow the collection of insects.

- A Malaise trap was used for 24 hours. This was a classic 2 metre high Malaise trap (S&S entrap net company: http://www.geocities.com/ssentrap/).

- A light trap, put directly on the ground, for 7 hours during the night was utilised (Vermandel Entomologie Speciaalzaak: http://www.vermandel.com/). Attention was paid for the light trap so that it was not impaired by artificial lighting.

- 2 coloured pan traps (15x12x5cm) were utilised: one yellow and one blue were put directly on the ground in each site for 48 hours. In these pans, soapy water was used to kill insects.

This study was carried out during a hot, sunny week from 3 to 6 of September 2002. The nights were dark since the new moon was the 7th of September 2002.

Hence, each location was sampled once with every trap. On each site, traps were used simultaneously but with different durations of working. In this respect, it was possible to compare different traps with a particular methodology.
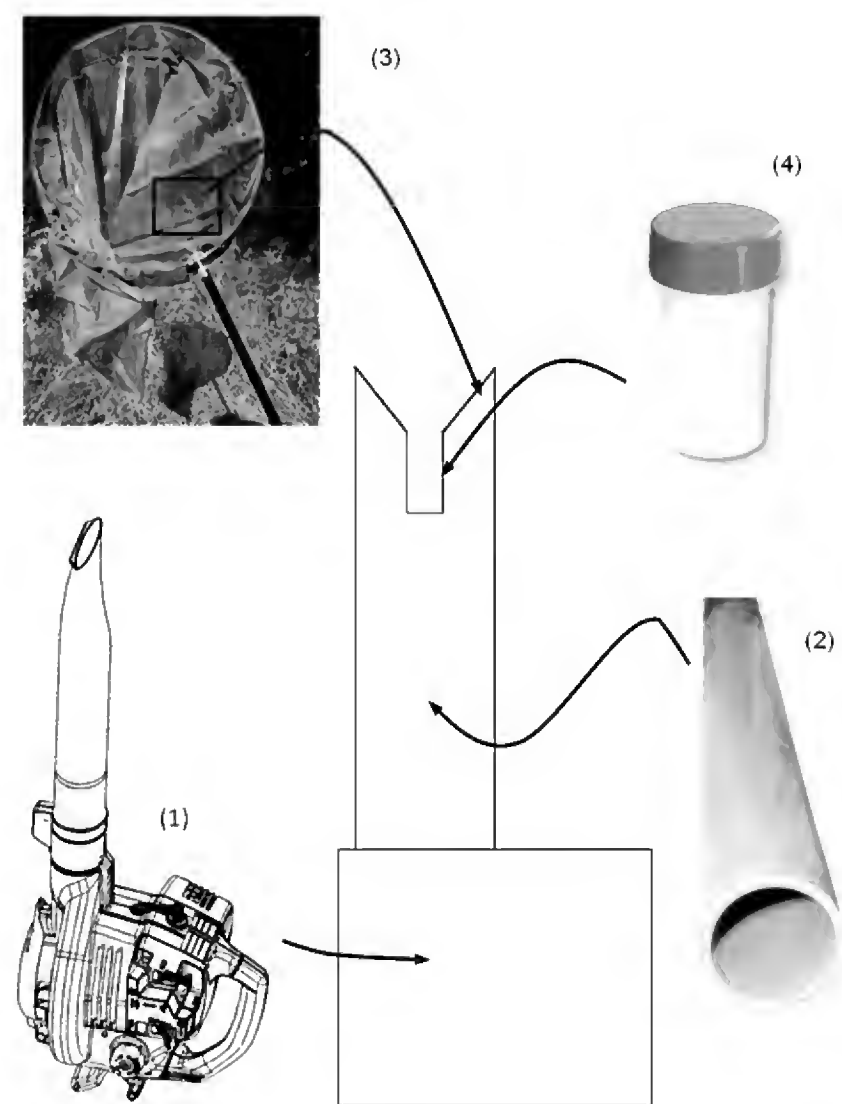

Figure 1. Suction trap. This trap consisted of a leaf blower/vacuum (1) (PARTNER-BV24) directed toward the sky. A 2.5 metre high pipe (2) was adapted (12cm diameter) in order to increase the height of capture. A funnel (made with a piece of net (3)) with a collecting bottle (4) was inserted into the pipe to allow the collection of insects.

RESULTS

Global analysis

First of all, the results demonstrate large differences in the effectiveness of the traps (Table 1). If the effectiveness of a trap is considered as a function of the number of organisms caught, it can be concluded that the Malaise trap is the most effective trap. Indeed, this trap caught twice more animals than the second most effective trap, the yellow pan trap (Table 1). Nevertheless, the durations of working of traps were different. Hence, if the number of capture per hour of working is observed, the suction trap is by far the most effective trap (Table 1). Secondly, regardless of the type of trap used, more than 86% of organisms caught were insects (Table 1). Furthermore, most traps caught only insects, for example Malaise traps seem specific for insects (Table 1). However there are a higher number of

other arthropods (mainly isopods and spiders) in blue pan traps.

During the period of this study, 1746 specimens were collected. Among these it was possible to determine the families of 1597 specimens. Due to deterioration or difficulty of determination, the remaining 149 specimens were identified as 15 Lepidoptera, 64 Trichoptera, 2 Diptera, 5 Hymenoptera, 18 Heteroptera, 44 Homoptera and 1 totally undetermined. This corresponded to a 5 to 13% of the total insects collected in four traps. Only in the light trap, 23% of the insects collected were assigned to the order mainly due to the difficulty of determination of Lepidotera (Heterocera). Indeed, in this last trap, many slugs were caught and their mucus damaged the collected insects.

Henceforth, when the study refers to insect order, the number of specimens considered is 1745 and when the study refers to insect families, the number of specimens considered is 1597.

During the trapping period, 72 insect families were collected and determined (Table 2). The results show that the Malaise trap caught more than 76% of the families collected (Table 2). The second most effective trap is the yellow pan trap which caught 61.1% of the families which is not significantly different to the Malaise trap (Fisher exact test, p= 0.072). The other traps caught less than 50% of the families determined which is significantly different from the two other traps (Fisher exact test, p<0.02). Both traps, Malaise and yellow pan, caught together 87.5% of the families. According to our results, to capture 90% of the families the use of three complementary traps would be necessary: the combination Malaise + yellow pan + blue pan traps (90.3%) or the combination Malaise + yellow pan + suction traps (93.1%).

The Malaise trap also seemed to show more specificity in captures since 12.5% of the families were caught by this trap only (Table 2). In contrast, less than 5% of the families were caught in each other trap individually. However, due to the weak level of specificity of the traps, no significant statistical results was found (Fisher exact test, p>0.07). More precisely, Diptera (Stratiomyidae, Empididae, Tanipezidae, Pipunculidae, Lonchaeidae, Sciomyzidae, Tephritidae), Hymenoptera (Halictidae) and Psocoptera (Stenopsocidae) were only caught by the Malaise trap (Table 3).

Generally, the Malaise trap is the most effective for Homoptera, Heteroptera, Psocoptera, Diptera. Malaise and yellow pan traps are equally the most effective in the capture of Hymenoptera (Fig. 2). For Coleoptera and Lepidoptera, the light trap was the most effective. Due to the small number of captures, the statistical analyses was possible only for Homoptera, Hymenoptera, Diptera and Trichoptera. There is a high significant statistical difference between the traps for these 4 orders of insects (χ^2 test, p< 0.005 for each order).

In the captures, diversity in families was very small for Orthoptera, Thysanoptera and Homoptera with only one family determined and for Psocoptera with only 3 families. Hence, at the family level,

Type of traps	Number of insects caught	Number of non-insects caught	Total number of insects and non-insects caught	Proportion of insects caught (%)	Average number of insects caught per hour
Light trap	129	2	131	98.5	18.43
Blue pan	90	14	104	86.5	1.88
Yellow pan	350	5	355	98.6	7.29
Malaise trap	939	1	940	99.9	39.13
Suction trap	238	8	246	96.7	476
Total	1746	30	1776	98.3	

Table 1. Number of individuals caught in the different traps used.

	Light trap	Blue pan trap	Yellow pan trap	Malaise trap	Suction trap	Total number of families caught
Proportion of families caught by traps	26.4 %[b]	40.3 %[b]	61.1 %[a]	76.4 %[a]	36.1 %[b]	72
Proportion of families caught by one trap only	4.2 %	2.8 %	2.8 %	12.5%	4.2 %	72

Table 2. Specificity of each trap and effectiveness of traps that means proportion of families caught by the different traps. Proportions with different letter were significantly different ($p<0.05$; Fisher exact test). Due to small number of families, statistical test was impossible for the proportion of families caught by one trap only.

	Diptera	Hymenoptera	Psocoptera	Coleoptera
Malaise traps	Stratiomyidae Empididae Tanipezidae Pipunculidae Lonchaeidae Sciomyzidae Tephritidae	Halictidae	Stenopsocidae	
Yellow traps		Ceraphronidae		Curculionidae
Blue traps	Platypezidae			Hydrophilidae
Light traps	Chaoboridae			Nitidulidae Smicrinidae
Suction traps	Scatopsidae	Torymidae Scelionidae		

Table 3. Specificity of capture. Insect families only caught in one kind of trap.

comparisons between traps are possible for Coleoptera (9 families caught), Diptera (38 families) and Hymenoptera (19 families).

Light traps caught a higher proportion of coleopteran families but it is not significant (Table 4). Malaise traps caught the majority of Diptera and Hymenoptera with 89.5% and 68.4% of families, respectively (χ^2 test; $\chi^2=40.7$, df=4, $p<0.0001$ and $\chi^2=18.7$, df=4, $p<0.001$, respectively). For each of these three groups, the yellow pan trap was the second most effective (Table 4). Different combinations of traps improved the captures. For example, the com-

bination light trap/yellow pan trap caught all the 9 families of Coleoptera together. For Diptera, the combination light trap/Malaise trap or the combination suction trap/Malaise trap caught 94.7% of families.

The combination of the two most effective traps: yellow pan trap/Malaise trap was not the best since it caught 89.5% of captures (difference was not significant). For Hymenoptera, the best combination was suction trap/Malaise trap with a total of 94.7% of captures; the second most effective combination was suction trap/yellow pan trap with a total of 89.5% of captures. Once more, the combination yellow pan

trap/Malaise trap was not the best since with 84.2% of catch that is the third combination (difference was not significant). 100% of captures of Hymenoptera families were obtained with the combination of three traps: Malaise trap, suction trap and yellow pan trap.

Analysis of trapping constancy

The comparison of effectiveness of traps between sites enables to check if the observations were constant from one site to another, and hence if some generalisations could be possible.

In proportions of insects caught during the trapping period (Fig. 3), the Malaise trap is the most effective for 4 out of 6 sites studied (χ^2 goodness-of-fit test; all p<0.001). For the two other sites, the Yellow pan trap is the most effective (χ^2 goodness-of-fit test; all p<0.001). However, the results did not show significant constancy in the proportion of insects caught by the different traps between the sites (heterogeneity χ^2 analysis, $\chi^2 = 236.5$, df =20, p<0.0001).

In proportions of families, the Malaise trap is the most effective since it caught a higher proportion of
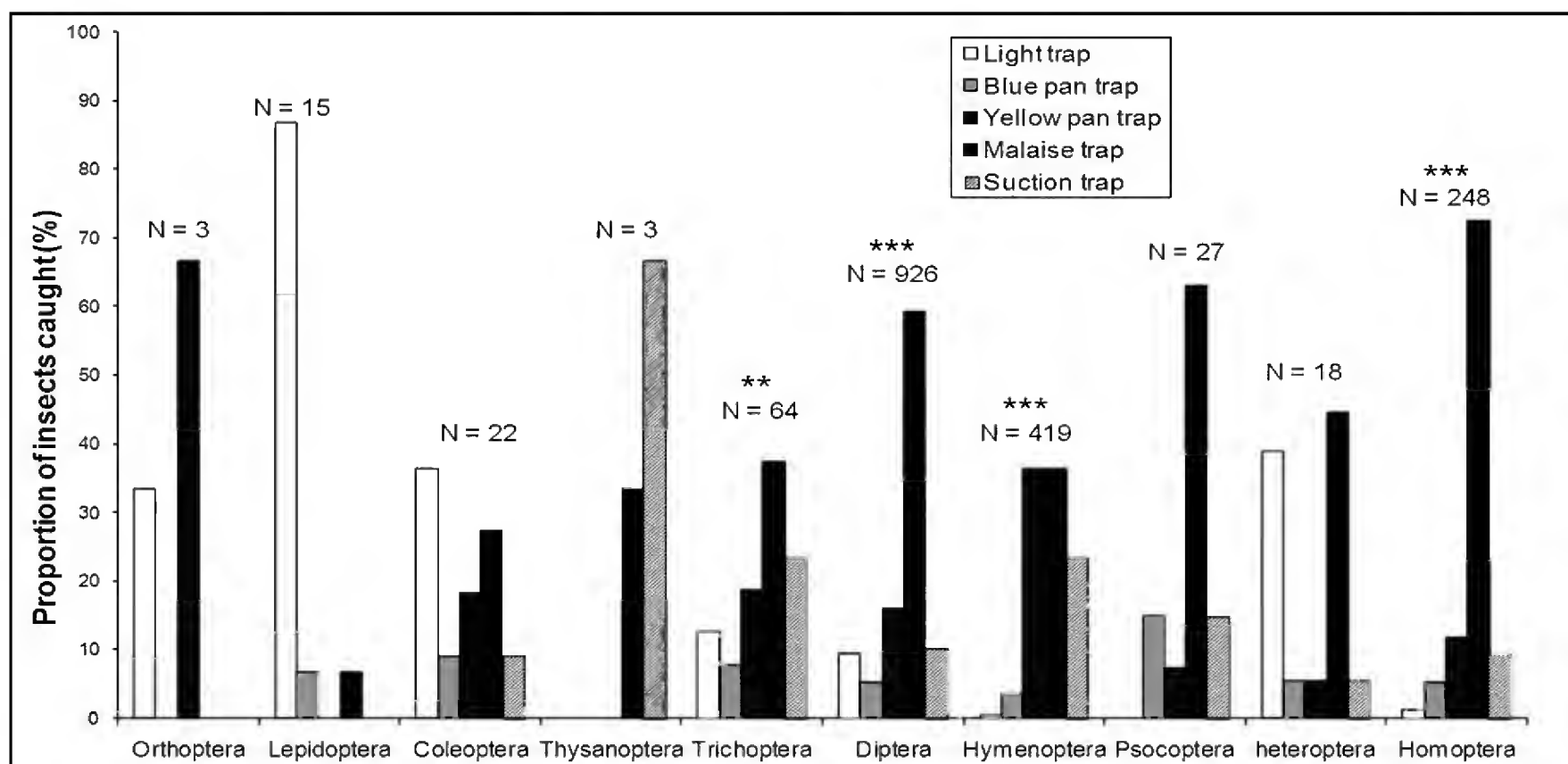
Figure 2. Proportion of insects caught by the different traps. N=total number of insects caught in each order. χ^2 goodness-of-fit tests were carried out for Trichoptera, Diptera, Hymenoptera and Homoptera (the number of insects in the other orders was too small to permit the analysis) to determine the highlight the differences between the traps. ** = p<0.005, *** = p<0.001.

	Light trap	Blue pan trap	Yellow pan trap	Malaise trap	Suction trap	Total number of families caught
Coleoptera	55.6%	11.1%	44.4%	33.3%	11.1%	9
Diptera	26.3%	47.4%	60.5%	89.5%	28.9%	38
Hymenoptera	10.5%	36.8%	68.4%	68.4%	57.9%	19

Table 4. Effectiveness of traps that means the proportion of families caught by each traps.

families in 5 out of 6 sites studied (Fig. 4). The yellow pan trap is the second most effective trap in these 5 sites and the most effective in the sixth one. In each location, the blue pan trap and light trap were the least effective in the collecting of numerous families of insects. In this respect, from one site to another one, no differences were found between pro-

portion of families caught by each trap (heterogeneity χ^2 analysis, $\chi^2 = 9.6$, df =20, p>0.05). Hence, the results showed constancy in the proportion of families caught by the traps in each location.

More precisely, concerning the constancy of captures, the results show that only Diptera were caught in every site by each trap. Hymenoptera and Ho-
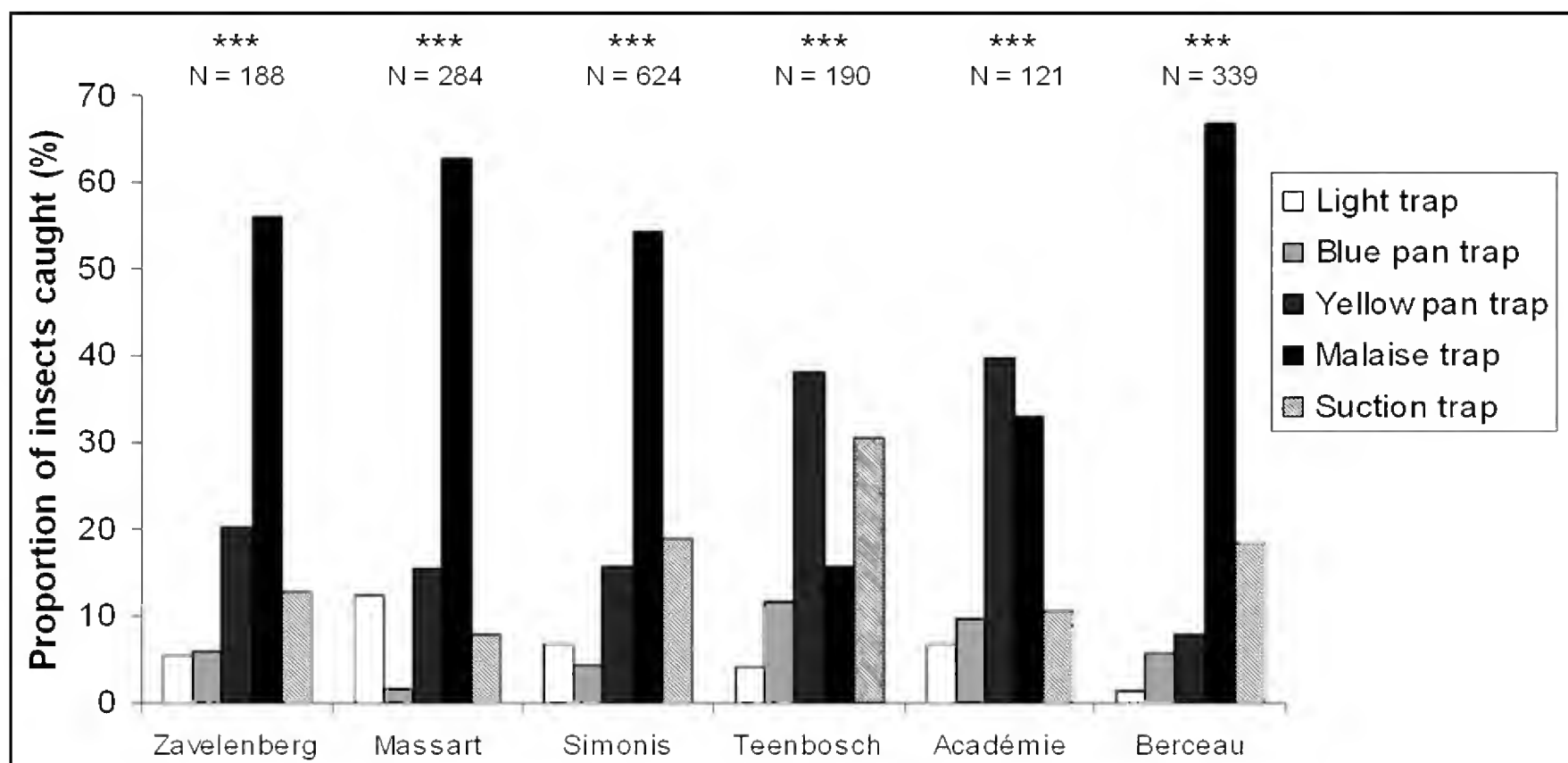
Figure 3. Proportion of insects caught by the different traps as a function of the trapping sites. χ^2 goodness-of-fit tests were carried out for each location to highlight the differences between the traps in each site. *** = p<0.001.
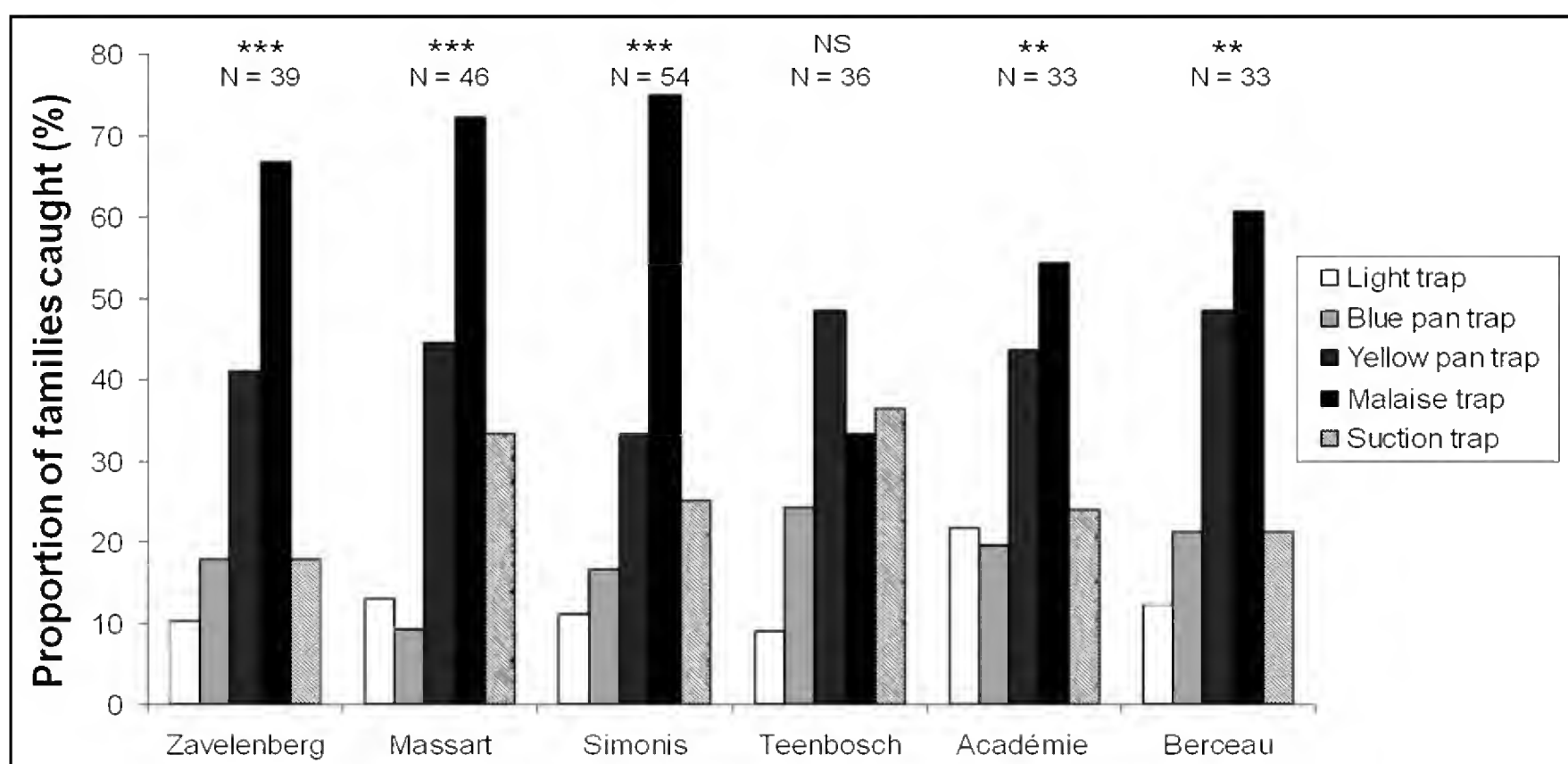
Figure 4. Proportion of families caught by the different traps as a function of the trapping sites. χ^2 goodness-of-fit tests were carried out for each location to highlight the differences in between the traps in each site. NS = Not Significant ** = p<0.01, *** = p<0.001.

moptera were collected in every site by Malaise, yellow pan and suction traps. Coleoptera were caught in 3 sites by Malaise, yellow pan and light traps. With the exception of one specimen caught in the Malaise trap and another in the blue pan trap, only light traps caught Lepidoptera (Heterocera).

Malaise traps were particularly effective in collecting some Diptera: Sciaridae, Phoridae, Muscidae and Sphaeroceridae, and some Homoptera: Aphididae. Indeed, these 5 families were found in the malaise trap in each location. In contrast, the other traps showed less consistency. Indeed, only two families (Hymenoptera: Pteromalidae and Mymaridae) were found in each suction trap. Similarly, only one family of Hymenoptera (Braconidae) and one family of Diptera (Ceratopogonidae) were caught in every location by yellow pan trap and light trap respectively.

DISCUSSION

In this study, the Malaise trap was most effective in terms of the largest catch of individuals and families when compared to the other traps. Moreover, more than 10% of insect families were caught by the Malaise trap only whereas the specificity of the other traps reached at maximum of 4% of insect families. Therefore, the better trap seems to be the Malaise trap. However, this trap is big and highly visible which could impede its use in urban locations because of potential vandalism acts. The same problem occurs with the light trap which could improve the trapping of nocturnal insects (for example Lepidoptera) but which is by definition visible because it is illuminated. The suction trap is very effective since it caught nearly 30% of Diptera and 60% of Hymenoptera while it was only used for 30 minutes. In a way, it can be concluded that this trap is the most effective since it captured a lot of insects in a very short period. However, this trap, in its design, is very noisy and thus could be difficult to use for a long time in urban areas. In summary, in some circumstances (e.g. residential urban areas), researchers may wish to choose the less effective traps as there is less risk from vandalism or causing disturbance.

In this study, different traps were used with very different durations of working. Indeed, the suction trap was working only 30 minutes whereas the pan traps were left on the ground during 48 hours. That could be a problem in analysis of their comparison.

However, the comparison of different traps with same duration would not be useful. For example if the aim is to compare the effectiveness between the Malaise trap and the suction trap, the use of Malaise trap during 30 minutes would be useless, or in contrast, the use of suction trap during 24h would be too damaging for the environment by depleting uselessly the abundance of insects. Hence, for further studies it is suggested that it is better to compare different traps used in their best methodology (Campbell & Hanula, 2007; Hardwick & Harens, 2007; Pendola & New, 2007; Blackmer et al., 2008) and not necessarily in the same methodology.

The results show that no trap alone is able to catch all insect families that we have captured during the trapping period. Indeed even if the suction trap is really effective it will capture only small airborne insects constituting the aerial plankton. However, some combinations are potentially very useful to improve trapping. Indeed, the combination suction trap/Malaise trap caught more than 94% of families of Diptera and Hymenoptera. The combination of the two most effective traps did not give better results, proving that same families could be caught by these two traps. More studies would be necessary to compare the numerous trap systems (Southwood, 1978) and the effectiveness of their association.

This study can be considered as very limited since the determination was carried out only at a family level. Hence, further studies are needed to verify whether the same holds true at genus and species level. However, the advantage of such broad generalizations is that trends can be quickly identified (Gaston & Williams, 1993; Andersen, 1995). Indeed, the study seems to indicate that some families (which could represent several hundred of species) are only caught by one trap. For example, if Malaise traps were not used in our samplings, more than 10% of insect families captured during the study could not be observed. Scientists and technical professionals need to have standardised observation methods (Agosti et al., 2000 but see Melbourne, 1999).

This standardisation should allow comparison to be made between sites, at the same sites at different time periods and by different people. Indeed, it must be kept in mind that results from one kind of habitat could be different from another. For example, the results present some differences with those from other studies: the captures by the blue

pan traps are very poor whereas these traps could be highly effective in catching Hymenoptera pollinators (Campbell & Hanula, 2007). Therefore, every site has specific attributes and the choice of traps based on a range of features (e.g. trapping efficiency but also resistance to the deterioration) could not be prone to "blind" standardisation methods. On the basis of the results of this study, it would be extremely beneficial to continue studies comparing the effectiveness of traps to help improve monitoring of insect biodiversity.

ACKNOWLEDGEMENTS

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Lectotype designation and descriptions of two new subspecies of *Amphidromus* (*Syndromus*) *laevus* Müller, 1774 (Gastropoda Pulmonata Camaenidae)

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ABSTRACT
Amphidromus (*Syndromus*) *laevus* Müller 1774 (Gastropoda Camaenidae) was described without a type locality. Sampling made in Indonesia over the last 20 years has confirmed the presence of this species on Kisar Island (Pulau Kisar) and the Leti Islands (Kepulauan Leti) of the southwestern Maluku Province. Similar shells have also been found at Tutuala, Timor L'este. However, none of these specimens represents the nominal taxon and so its type locality is still to be determined. Sampling made in recent years on Roma (Pulau Romang) has not located any specimens of *A.* (*S.*) *laevus romaensis* Rolle, 1903. Herein a lectotype for *A.* (*S.*) *laevus* is designated and two new subspecies are described from the Leti Islands: *A.* (*S.*) *laevus janetabbasae* n. ssp. from Western Moa Island (Pulau Moa) and *A.* (*S.*) *laevus nusleti* n. ssp. found on Leti Island (Pulau Leti).

INTRODUCTION

It has been 240 years since *Amphidromus* (*Syndromus*) *laevus* Müller, 1774 was first described, and its type locality still has not been determined. Previous authors usually stated imprecise localities for specimens of *A.* (*S.*) *laevus* (sensu lato), such as islands of Moluccas (Malaku Islands) (Fulton, 1896). Prof. von Martens (1867) said he had obtained this species while on Amboina (Ambon) from Mr. Hoedt, and other collectors indicated to him they had found it on the Tenimber (Tanimbar) Islands. In 1877 von Martens stated that Captain Schulze found it on Keffing Island close to Ceram (Seram), Moluccas. In addition to these imprecise or generic localities, Laidlaw & Solem (1961) added Java, Timor and Singapore; although they considered Keffing as a doubtful locality. No specimens of *A.*

(*S.*) *laevus* (s.l.) have been found on Ambon, Seram and the Tanimbar Islands in recent years, and here considered as doubtful localities until von Martens' specimens can be located and studied. This study has determined that this species does not live on both Java and Singapore, and so they are erroneous localities.

Specimens of *A.* (*S.*) *laevus* (s.l.) deposited in the Field Museum of Natural History (FMNH, Chicago, Illinois, USA) are from field trips in 1998. This confirms that this species lives on the islands of Leti, Moa and Lakor of the Leti Group (Kepulauan Leti), and Kisar Island (Pulau Kisar), southwestern Maluku Province (Provinsi Maluku) of Indonesia (Severns, 2006). Shells comparable to this species, *A.* (*S.*) cf. *laevus*, live near the eastern most point of Timor L'este at Tutuala, which is close to Leti and Kisar Islands (collections of
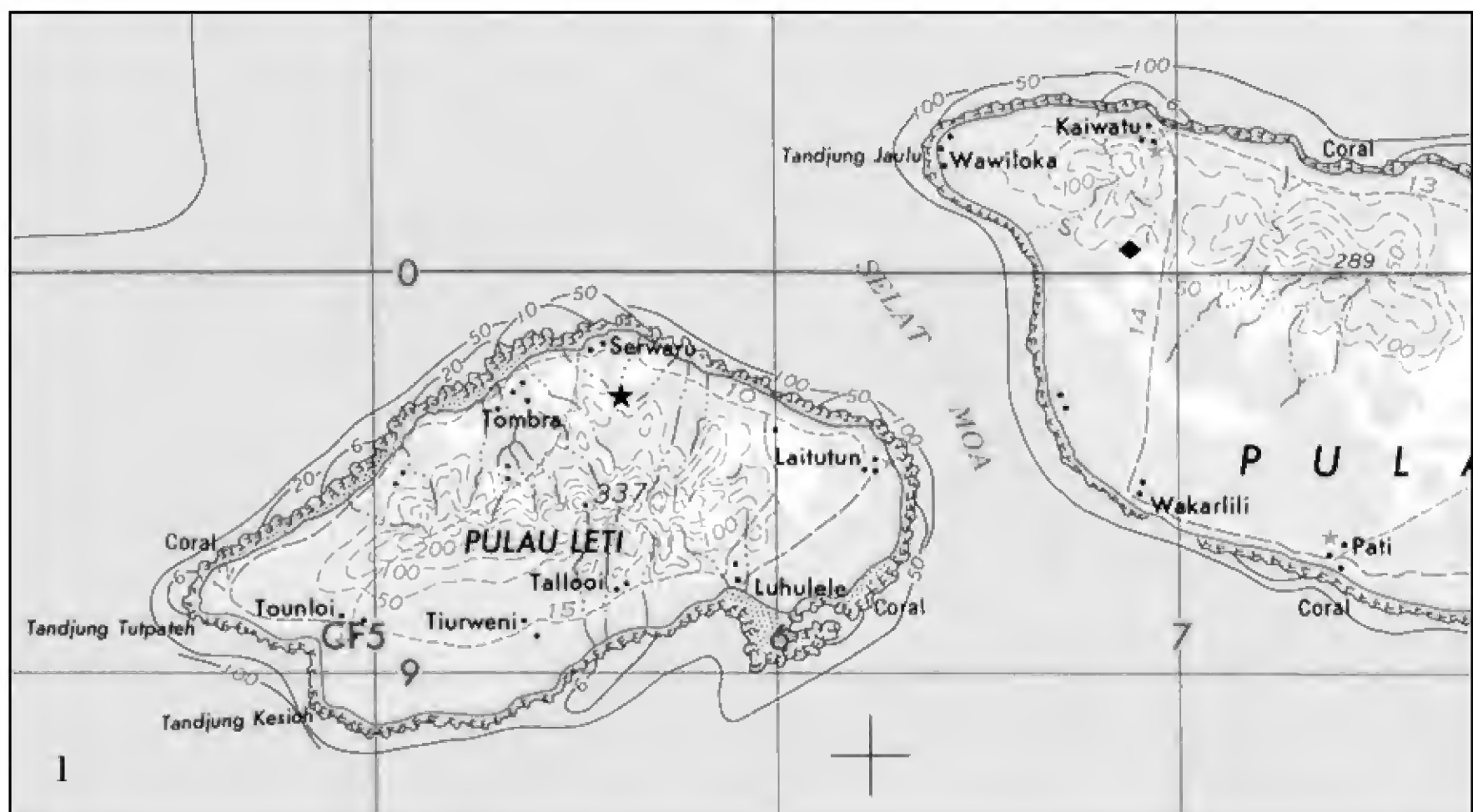
Figure 1. Map showing the approximate positions of the type localities for *Amphidromus* (*Syndromus*) *laevus nusleti* n. ssp. on Leti (black star) and *A.* (*S.*) *laevus janetabbasae* n. ssp. on Moa (black diamond) (modified from a map of "Palau Moa" including nearby islands: Army Map Service, Corps of Engineering (U.S. Army) 1963).

FMNH and JP). Field collections by John Abbas confirm *A.* (*S.*) *laevus* (s.l.) lives on Kisar (2008–2012).

Misidentification of other species as *A.* (*S.*) *laevus* (s.l.) has certainly occurred and led to erroneous locations. Misidentified species and shells labelled as "Timor" in museums are still under investigation and not discussed here.

In 2012, John Abbas organised field trips to Leti and Western Moa (see map, Fig. 1). These confirmed *A.* (*S.*) *laevus* (s.l.) lives on Leti and discovered a distinct population on Moa. Moa is the largest of the three main islands in the western part of the Leti group, separated by narrow channels from both Leti to the west (Moa Strait or Selat Moa) and Lakor to the east (Lakor Strait or Selat Lakor). A syntype of *Helix laeva* Müller, 1774 is selected as the lectotype of *A.* (*S.*) *laevus* and a detailed description is given. Detailed descriptions are also given for *A.* (*S.*) *laevus romaensis* Rolle, 1903 (lectotype) and *A.* (*S.*) *laevus kissuensis* Rolle, 1903 (lectotype), in addition two new subspecies are herein described as *A.* (*S.*) *laevus janetabbasae* n. sp. from Moa and *A.* (*S.*) *laevus nusleti* n. sp. from Leti.

MATERIAL AND METHODS

In the absence of preserved anatomical material or living animals for study, the descriptions are based on the morphological analyses of dry empty shells. Shells available for the present study are stored in the author's private collection (including a single shell from Tutuala) (JP) and supplied by John Abbas (JA). Comparisons of some subspecies could only be made using digital images, supplied by museum staff, syntype of *A.* (*S.*) *laevus*, anonymous sources, *A.* (*S.*) cf. *laevus* from Tutuala and Lakor, and from online access of museum collections (lectotypes of *A.* (*S.*) *laevus romaensis* and *A.* (*S.*) *laevus kissuensis*). Müller's measurement of "lin." is assumed as the obsolete Danish linie (English line), which is 2.18 mm (Stöver, 2001) and his measurements are converted accordingly. Relative sizes of shells for the subgenus *Syndromus* mentioned: small < 30 mm; medium 30–45 mm; large > 45 mm.

Shell sculpture was examined under low magnification (10x) using a jeweller's loupe. All shells examined had formed a lip; those with a thickened lip were determined as adult and those with a thin

lip as subadult. The digital vernier calliper used to measure all shells has a resolution of 0.01 mm (Table 1). Measurements for specimens in digital images were calculated with the included scale bar. The five shell dimensions measured are (Figs. 2, 3): shell height (H), maximum shell width (D) and aperture height (AH) (measured including the lip); shell width above the aperture (d) and umbilical width across the opening (U). The columella angle (CA) was measured by placing a protractor over digital images of shells, with the shell axis as the zero degree point (Figs. 2–4). Number of whorls (N), include the apex and the teleoconch and counted precise to 0.125 (⅛ whorl) as per Haniel (1921) (Fig. 4). Measurement of the perch angle (PA) follows Dharma (2007). The ratios of shell height to shell width (H/D) and aperture height to shell height (AH/H) were calculated as indices of shell shape.

In order to make a comparison of banding patterns in *A.* (*S.*) *laevus*, von Martens (1867) counted only the dark bands on the last whorl and utilized a similar numbering system to that used for studying banding in pentataeniate (five-banded) Helicids

(e.g. Taylor, 1914; Cook & King, 1966; and Cook, 1967). Modifying his method for a pattern of six dark bands: the count starts below the suture from the highest of the superior bands (1 and 2), through the peripheral bands (3 and 4) to the lowest or basal bands (5 and 6). Each band present is given a number when present and a zero when absent. When all six bands are present, this gives a formula of 123456. Numbers placed in rounded brackets show two or more bands that have fused to form a wider single band, e.g. 1234 (56). Two numbers underlined represent a band pair that has connected to form a two-toned band, e.g. 12<u>34</u>56. Indistinct and partial bands are shown by a colon, e.g. 1:3456. Haniel (1921) used a slightly modified method by describing the pattern as seen on the last half whorl.

Two independent spiral band networks combine with a band around the umbilicus (circumumbilical band) to form the basic shell pattern as seen on the last whorl. Each network has three band zones occurring in alternate positions, with these named by position starting from below the suture working anteriorly toward the umbilicus. The first network has
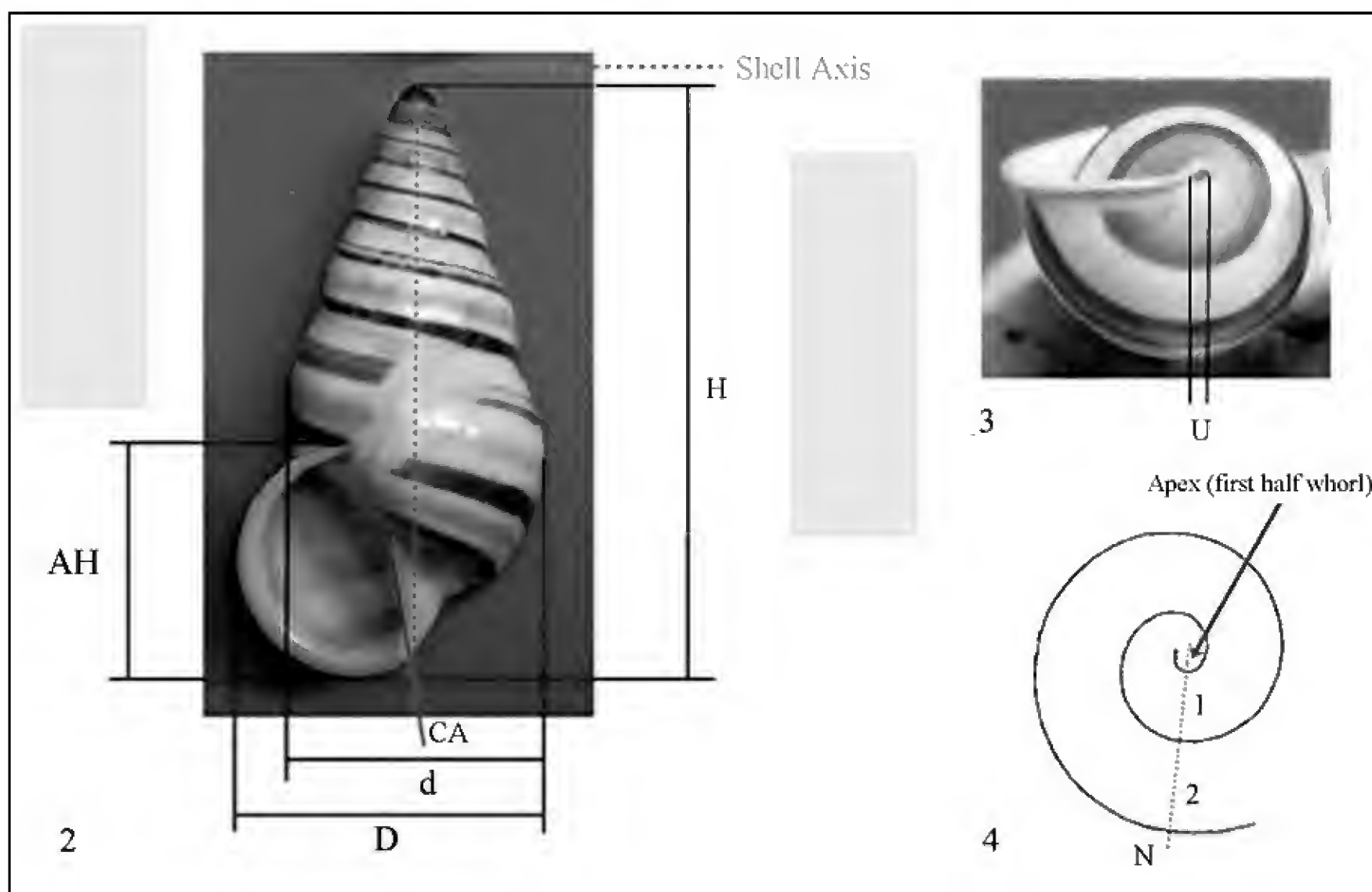
Figures 2, 3. Shell dimensions, see Material and Methods for explanation of abbreviations, and Figure 4: method of whorl count (N) (Haniel, 1921)

Measurement	Species	Amphidromus (Syndromus) laevus					
	Subpecies	laevus (L)	cf. laevus	janetabbasae	kissuensis	nusleti	romaensis (L)
	Locality	unknown	Tutuala	Moa	Kisar	Leti	Roma
	Count	1	1	25	15	19	1
AH (mm)	range			12.06–17.04	12.26–15.47	12.36–16.59	
	average	11.83	18.54	15.05	14.03	14.04	18.27
AH/H (ratio)	range			0.36–0.47	0.38–0.44	0.41–0.47	
	average	0.45	0.42	0.43	0.41	0.44	0.41
CA (degrees)	range			5 to 20	6 to 18	5 to 20	
	average	5	5	10.56	11.47	10.11	5
N	range			5.625–7	5.25–6.875	5.375–6.5	
	average	5.50	6.5	6.25	6.25	5.888	7
PA (degrees)	range			16–25	18–24	18–24	
	average	NA	21	19.72	21.67	21.68	NA
H (mm)	range			27.59–44.21	29.57–40.52	27.07–36.30	
	average	26.26	44.23	35.19	34.45	31.72	45.06
D (mm)	range			15.35–19.69	14.93–20.41	14.77–21.26	
	average	14.69	21.78	17.73	17.68	16.89	22.95
d (mm)	range			12.30–16.50	13.09–16.91	10.73–17.51	
	average	12.71	18.19	14.92	15.12	13.62	18.70
H/D (ratio)	range			1.78–2.43	1.77–2.38	1.69–2.11	
	average	1.79	2.03	1.98	1.95	1.88	1.96
U (mm)	range			0.66–1.84	0.47–1.10	0.54–1.34	
	average	NA	0.71x1.48	1.20	0.93	0.98	NA

Table 1. Comparative shell measurements for the subspecies of *Amphidromus* (*Syndromus*) *laevus*. Data given as aperture height (AH); aperture height to shell height ratio (AH/H); columella angle (CA), offset to shell axis; whorl count (N), including apex (to nearest ⅛ whorl);perch angle (PA); shell height (H); shell width (D); shell width above the aperture (d); shell height to shell width ratio (H/D); and umbilical width (U). Note: L = lectotype; count is the number of specimens measured; and the umbilicus of *A*. (*S*.) cf. *laevus* (s.s.) from Tutuala is elongated whorl count (N) (Haniel, 1921)

generally pale coloured bands found below the suture (subsutural), middle of the upper half whorl (supermedial) and middle of the lower half whorl (submedial). The second network usually has dark coloured bands between the subsutural and super-medial bands (superior), near or on the periphery (peripheral) and between the submedial and circum-umbilical bands (basal).

According to the International Commission on Zoological Nomenclature (ICZN) code (1999), Article 72.4, Müller's type series includes one spec-imen (alpha) examined by him from the Spengler collection (Museo Spengleriano) and a cited speci-men (beta) described and illustrated by Lister (1685). The colour variant beta described by Müller was unavailable for morphological examination or comparison through a photo.

A large part of Spengler's collection is de-posited in the Zoological Museum, University of Copenhagen, Copenhagen, Denmark (ZMUC). Thanks to the help of Danny Eibye-Jacobsen, the specimen examined by Müller has been located in their museum. This shell was compared to the orig-inal description (Müller, 1774) and opinions of Chemnitz (1786), using photos supplied (ZMUC). This shell matches the dimensions given by Müller and the illustrations given by Martini (1777) and Chemnitz (1786), and is here considered as the actual shell seen by Müller. In absence of any other typical material with a known locality, under the terms of the ICZN code (1999), Article 74.7, this shell is here designated as the lectotype and discussed below.

Some taxonomic comments are required. Firstly, there has been some confusion made recently that the shells from Leti are a rediscovery of the nominal taxon (John Abbas pers. comm.). Those particular shells do not match Müller's type shell and they are herein described as a new subspecies. The nominal taxon remains an unlocalised species, since the labels found with the lectotype shed no light on the type locality. Secondly, certain shells from Kisar have been circulating among collectors incorrectly labelled as A. (S.) laevus romaensis Rolle, 1903 (John Abbas pers. comm.), which is a distinct form of its own and discussed below.

ABBREVIATIONS. Type material of the herein newly described subspecies of A. (S.) laevus have been deposited in the Australian Museum, Sydney, New South Wales, Australia (AM); the Natural History Museum, London, England, UK (NHMUK); and Aquazoo/Löbbecke-Museum, Düsseldorf, Germany (LMA). Some additional type specimens belong to the private collection of John Abbas (JA) and private collection of the author (JP). Digital images of other type shells studied are from Senckenberg Naturmuseum, Frankfurt, Germany (SMF) and Zoological Museum, Univer-sity of Copenhagen, Copenhagen, Denmark (ZMUC).

SYSTEMATICS

Family CAMAENIDAE Pilsbry, 1895
Genus *Amphidromus* Albers, 1850
Subgenus *Syndromus* Pilsbry, 1900

Amphidromus (*Syndromus*) *laevus laevus* Müller, 1774

Helix laeva Müller, 1774: pp. 95–96, No. 293 (not illustrated)

EXAMINED MATERIAL. Digital images of a single syntype specimen from the ZMUC (Danny Eibye-Jacobsen), ex. Spengler Collection, and this is herein designated as the lectotype ZMUC-GAS-274 (Figs. 5, 6); dimensions: H 26.26 mm; D 14.69 mm; d 12.71 mm; and H/D of 1.79; type locality: unknown, original labels are without locality data (Figs. 8, 9).

DESCRIPTION OF THE LECTOTYPE. Shell small (26.26 mm high), sinistral, obliquely perforate (col-umella hollow) and relatively solid. Shape ovate-conic with a moderately elongated spire. Surface is scarcely glossy; without macrosculpture. Micro-sculpture (as determined from digital images): protoconch (embryonic whorls) smooth; teleo-conch (post-embryonic whorls) with numerous very fine growth threads with microscopic growth lines in the interspaces. Whorls about 5½, distinctly convex apically, next ones flatly convex and lowest a little convex; base angularly-rounded. Coiling is regular, the last whorl hardly descend-ing in front. Suture weakly impressed apically, shallow on the teleoconch with a faint white mar-ginal line. Remnants of a pale cream periostracum partially cover the last half whorl. Protoconch of about 1½ whorls, bulbous; infrasutural band opaque

cream, translucent pale flesh below. Apex (first half whorl) obtusely pointed and a little exsert; opaque cream (pale apical spot). Transition to the teleoconch is weakly distinguished by a change in whorl convexity and ground opacity. Teleoconch pale flesh apically, following whorls dirty white grading to white on the last.

Shell pattern is formed by a combination of two independent spiral band networks, each with three zones in alternate positions, and a circum-umbilical band. A white subopaque stripe (mora) about 1 mm wide, divides the bands clearly early on the penultimate whorl; and ends in an opaque greyish resting line, representing the former lip of a resting stage (see Figs. 5, 6). Using Haniel's (1921) method of describing the pattern as seen on the last half whorl, the band formula for this shell is 023456.

Aperture oblique, semiovate and less than half of the total shell length (0.45); very pale yellow inside, clearly showing the external bands, but the violet ones are stained brown. Parietal callus scarcely perceptible, a thin colourless glaze; at the posterior end of its margin, a very short thickened lump adjoins the termination of the outer lip (parieto-labral tubercle), with nothing developed at the anterior end. Outer lip (labrum) white, very thin, subreflexed and barely expanded, white margined within the aperture. Columella white, narrow and thin-walled; subvertical, angled away from the aperture ventrally (abaperturally angled); twisted apically before straightening to join with the basal margin at an angle; weakly grooved at its root. Columellar margin narrow, revolute, dilated above and tapering to a narrow base, partially covering the narrow umbilicus. Interior of umbilicus (umbilical interior) blocked in ventral view.

ANIMAL AND SOFT PARTS. Details unknown.

DISTRIBUTION. Unknown.

BIOLOGY. Unknown.

COMPARATIVE NOTES. The *A. (S.) contrarius* group from West Timor, which includes the nominate form and two accepted subspecies, share some similarities with *A. (S.) laevus* (s.s.). Each of the *A. (S.) contrarius* subspecies has pattern varieties that are partially marked with continuous bands on the spire or lower whorls, but usually the bands are interrupted and indistinct or obsolescent.

Rarely some shells of *A. (S.) contrarius nikienesis* Rensch, 1931 develop banding like that of *A. (S.) laevus* (s.s.) (Fig. 18). Haniel (1921) indentified such shells as being *A. laevus* 'of the literature'. These *laevus*-like shells have 3 to 6 purplish or brown bands on the last whorl. The dark bands of *A. (S.) laevus* (s.s.) are reddish brown and violet bands on the exterior surface, and brown on the interior surface. Some shells of *A. (S.) contrarius nikiensis* have a similar disparity, with purple or greenish external markings appearing brown internally (Figs. 16, 19). The overall shell shape, structure of the lip and columella, and lack of a dark apex suggests *A. (S.) laevus* (s.s.) has a close connection to *A. (S.) contrarius nikiensis.*

The shape and form of the columella is also comparable to some species of the *A. (S.) inconstans* group, e.g. *A. (S.) inconstans* Fulton, 1898 and *A. (S.) wetaranus* Haas, 1912. These species have the root of the columella weakly impressed, as does *A. (S.) laevus* (s.s.). However, in *A. (S.) laevus* (s.s.) it is probably due to a lack of calcification and not a distinctive feature of the species. A faint yellow tint may occur on the columella and lip in shells of *A. (S.) wetaranus.* If the columella of *A. (S.) laevus* (s.s.) truly had a yellow tint when inspected by Müller, it has since faded to white.

Shells of *A. (S.) cf. laevus* from Tutuala, Timor L'este and *laevus*-like shells display another pattern variation. Both commonly have solid dark bands connected by alternating pale and dark blotches (maculated zones) on the spire and solid or split bands on the last whorl. In *A. (S.) cf. laevus* these maculated zones develop from bands with a paler central zone (two-toned bands), which becomes interrupted medially by pale coloured spots that fade-away before the last whorl. In the *laevus*-like shells, the maculated zones form by wide single superior and peripheral bands becoming interrupted medially by pale coloured spots, which are later stained pinkish brown. The dark blotches fade-away to leave a pinkish brown central zone between each pair of purplish or brown bands, creating two-coloured bands on the last whorl. These maculated zones are absent in *A. (S.) laevus* (s.s.), which instead has a few faded blotches discoloured to brown on the superior band; and the two peripheral bands suffer pigment leakage and become connected to form a two-toned band, pale centrally. All three taxa show variation in the band

colour (tonal variation) creating intermittently faded bands.

A. (*S.*) *laevus* (s.s.) is here judged as a distinct species. It can be separated from *A.* (*S.*) *contrarius nikiensis* by the following features: lip fused to the body whorl; a minute parieto-labral tubercle at the lip termination; continuous violet spiral bands; no solid flammules; no vague flammules formed from aligned dashes of interrupted bands; and nascent reddish brown subsutural, supermedial and submedial medial bands.

REMARKS. The measurements of the shell as positioned in the photos (Figs. 5, 6) give H 26.26 mm, D 14.69 mm and d 12.71 mm; and shell breadth (B) is 13.42 mm (Fig. 5). Here H and B approximately fit Müller's measurements of length 26.16 mm and breadth 13.08 mm, so it would seem Müller measured this shell in a similar position to that in figure 5. Original labels with the specimen (Figs. 8, 9) refer to the first illustrations made of it (Figs. 13, 14), with one label designating it as the type shell (Sp.) and states *Helix laeva* α Müll. (Fig. 9).

Müller described the colour of external surface as lutescit, meaning coloured like white clay or white with a muddy hue. Several times he described the colour of the columella as lutea, assumed to mean yellowish. The columella is now white with some dirt inside, which blocks any view inside the umbilicus to determine if it is white or tinged with the colour of the circumumbilical band. Müller may have been referring to this dirt giving the columella a yellow tint at the time. He also described the shell as having six brown bands, which must be referring to the bands as seen inside the aperture. Figures 5 and 6 show a subreflexed lip, so it is probably a subadult. The faint trace of a subsutural band is visible behind the lip in the original digital images, but lost in figure 6.

What is distinctive about this shell is the very pale yellow palatal wall, which may have been darker when collected in the 18th century. This feature is absent in subadults of the other subspecies of *A.* (*S.*) *laevus*. It is not peculiar to this species and is discussed further below.

This shell was not figured by Müller and first figured by Martini in 1777 (Figs. 13), who wrongly confused it with *Helix inversa* Müller, 1774 (*A.* (*S.*) *inversus*). Chemnitz later figured it in 1786 but only the dorsal view (Fig. 14). Three shells were located

in the ZMUC with a label identifies them as *Orthostylus laevis* (note "*laevis*" the typographical error taken from Pilsbry, 1900). Another label references the shell figured by Lister (1685) (Fig. 10), thus suggesting they are Müller's variation β. Photos taken by Tom Schiøtte (ZMUC) show them to be one adult and two juvenile shells indentified as *A.* (*S.*) *contrarius* Müller, 1774. This is possibly a case of the labels being mixed up with the wrong specimens. This would mean that Müller's variation β is still to be found.

Müller noted a shell that Gualtieri figured in 1742 (Fig. 11) is this species except for being dextral. However, he did not mention the fact that in the same volume he had named that particular shell as *Helix terebella* (species number 319, p. 123). It is now accepted as *Pyramidella terebellum* Müller, 1774 (Fig. 12), or as a synonym or subspecies of *P. dolabrata* Linnaeus, 1758. Müller (1774) placed the latter as species number 318 on pages 121-122, accepting both as being terrestrial. Müller's comparison between the two species must be due to the similarity in ground colour and banding pattern. The obvious differences are *P. terebellum* has a columella with three folds, a simple lip, a sharply attenuated spire and it is a marine species, not terrestrial like it was assumed to be at the time.

Chemnitz (1786) figured other shells that he identified as *A.* (*S.*) *laevus* (Tab. 111, fig. 941-948). His fig. 940 is Müller's type shell (Fig. 14) and shown marked with bluish (actually violet) and brown bands, yet he repeats Müller's description of it having six red brown bands. Yet for fig. 941 (Fig. 14), he clearly mentions that shell is white with three reddish or bluish (possibly violet) bands, which appears to mean reddish brown on the spire and bluish on the last whorl. When comparing both shells, there is enough resemblance to suggest they were possibly collected from the same population. Unfortunately, this shell is yet to be located and so was unavailable for this study. Chemnitz's fig. 949 is excluded because it is *A.* (*S.*) *furcillatus* Mousson, 1849. It does appear that subsequent authors (e.g. Reeve, 1849; von Martens, 1867 and 1877; and Pilsbry, 1900) have accepted Chemnitz's account of *A.* (*S.*) *laevus* as accurate, and have considered every shell similar in appearance to those he figured and described as being the same species.

Amphidromus (*Syndromus*) *laevus romaensis* Rolle, 1903

TYPE MATERIAL. Lectotype designated by Zilch, 1953 (Laidlaw & Solem, 1961; p. 654), currently in the SM (Malakologie - SMF, 7574); ex. Sig. O. v. Moellendorff collection (ex. H. Rolle); dimensions: H 45.06 mm; D 22.95 mm; and H/D of 1.96; type locality: Roma (Romang) Island, northeast of Kisar and east of Wetar, Barat Daya Islands (Kepulauan Barat Daya), Southwest Maluku Regency, Maluku Province, Indonesia.

DESCRIPTION OF THE LECTOTYPE. Shell large (45.06 mm high), sinistral, obliquely perforate and very solid. Shape ovate-conic. Spire tall and regularly tapered. Surface is glossy. Macrosculpture (unmagnified): last whorl with occasional ridgelets, more numerous towards the lip. Microsculpture (as determined from digital images): protoconch smooth; teleoconch with growth lines and very fine growth threads. Whorls about 7, regularly increasing in convexity; base rounded becoming angularly-rounded behind the lip. Coiling is subregular with the last whorl descending toward the lip. Suture weakly impressed apically; shallow on the teleoconch with a thin white marginal line, more distinct on the last whorl. Periostracum thin, pale tawny and covers only the last whorl, thickening toward the lip. Protoconch is opaque, dome-shaped, about 1½ whorls; infrasutural band whitish; and pale yellowish below fading away on the second whorl. Apex opaque whitish (pale apical spot), obtusely rounded and protruding. Transition to the teleoconch is distinguished by a change in whorl convexity. Teleoconch pale yellowish apically, following whorls white without gradation to a yellow last whorl.

Pattern combination as per the nominal subspecies, but differs in band colouration and process of modification. A single whitish mora about 1 mm wide occurs close to the end of the penultimate whorl, preceding a very thin and quite distinct greyish resting line. The ground colour is rapidly changed to yellow and banding modified after the mora (post-mora modification) (see Fig. 21). The banding pattern as seen on the last half whorl, gives a formula of 023450.

Aperture oblique; strongly curved posteriorly, semicircular and about 41% of the shell height; yellow deep inside and weakly showing the external bands, white callused toward the lip. Parietal callus very thin and colourless on the upper part; lower third is white and flatly thickened toward a lump beside the root of the columella (parieto-columellar tubercle). Outer lip reflected, expanded and thick; lower half with a vertically reflexed edge (rimmed). Columella white, thick, rounded and wide; subvertical and abaperturally angled ventrally; oblique and leaning outwards (proclined) laterally; forms a distinct angle where it joins the basal margin (columellar-labral junction); its base is gently curved out (excurved) and projecting a little. Columellar margin broad; a little dilated above and rolled over the narrow umbilicus. Umbilical interior is indiscernible in the digital images.

ANIMAL AND SOFT PARTS. Details unknown.

REMARKS. Laidlaw & Solem (1961: 654) considered it to be a variety of *A.* (*S.*) *laevus* based on the fact the distribution of the nominotypical form was not known. However, it is regarded by the SMF as being *A.* (*S.*) *laevus romaensis* Rolle, 1903. The shell is clearly marked as being the type shell indicated by the letter "T." inside the aperture along with its catalogue number (Fig. 21 centre). The "a" at the end of the catalogue number does indicate a second specimen, however, Rolle (1903) mentioned only one specimen and a search of the SMF database (SeSam - Forschungsinstitut Senckenberg 2013) only located a single specimen. There is no scale bar included in the digital images found on the SMF database (Fig. 21) and no measurements given either, so the measurements given by Rolle (1903) are accepted as accurate. After taking measurements from these digital images, it was concluded that Rolle measured "D" parallel to the suture and "H" perpendicular to that plane with the shell viewed ventrally (Fig. 21 centre).

A number of field trips to Roma over the last 3 years have not confirmed the presence of this subspecies (John Abbas, pers. comm. 2013). Laidlaw & Solem (1961, p. 573; FMNH, specimen CNHM 97362) mention another specimen; this shell was unavailable for this study. A further search on Roma is required to determine if it is still present or ever was found on Roma, may be it was found on a nearby satellite island instead of on Roma itself. For now, due to its distinct appearance the current status of this subspecies is accepted as valid.
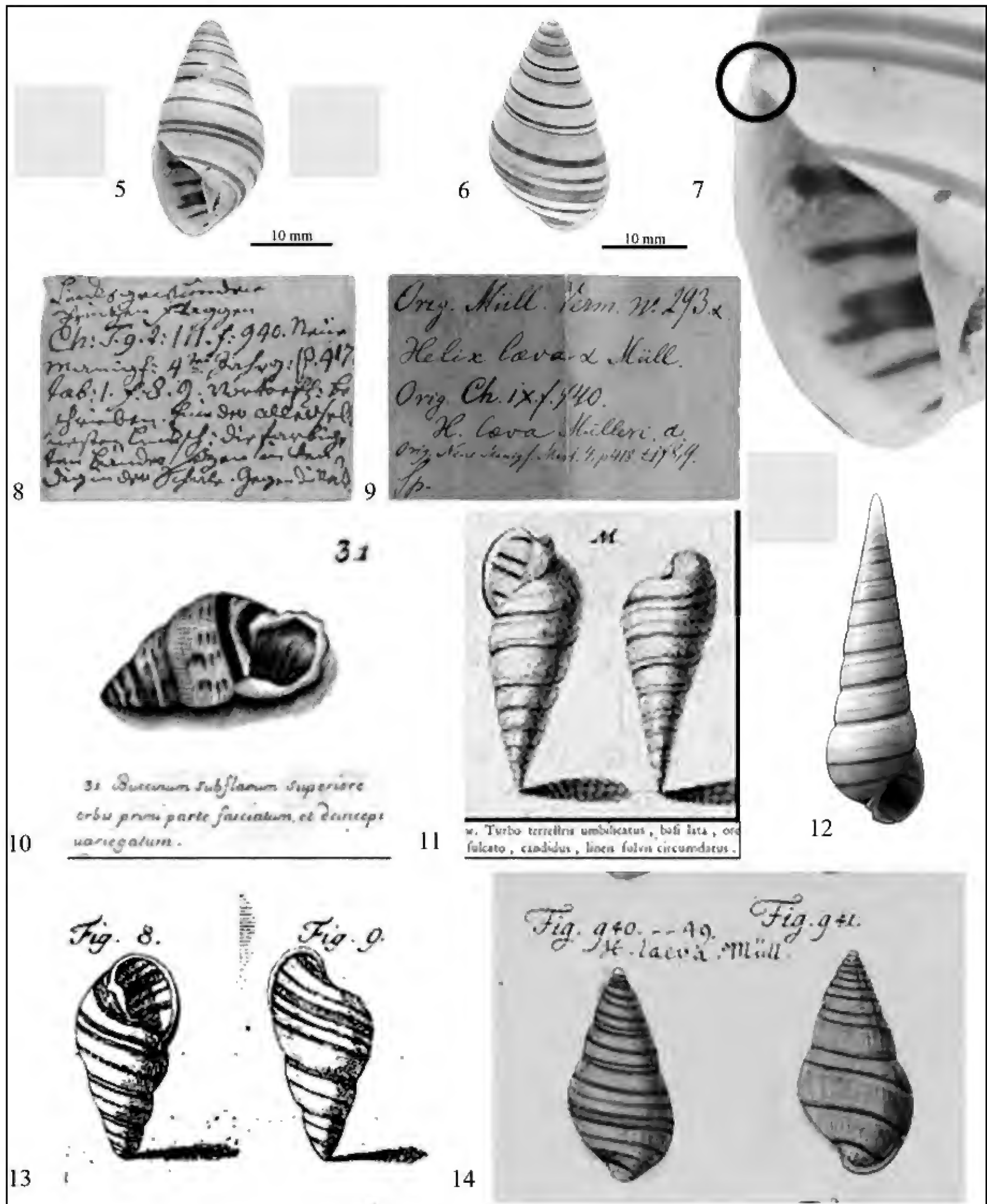
Figures 5–7. Nominotypical subspecies *A.* (*S.*) *laevus laevus*: Figs. 5, 6. Lectotype, ZMUC-GAS-274 ex. Spengler Museum. Figs. 8, 9. The original hand written tags with the lectotype, both citing the illustrations by Martini (1777) and Chemnitz (1786), with (Fig. 9) identifying this specimen as the type shell, indicated by "Sp.". Fig. 7. Closer view of the parieto-labral node (circled) (Photos by Tom Schiøtte, ZMUC). Fig. 10. Shell figured by Lister 1685 with text (t. 33, f. 31). Fig. 11. Shell figured by Gualtieri (1742) with text (t. 4, f. M). Fig. 12. *Pyramidella terebellum* shown here for comparison (Maurice, 2013). Figs. 13, 14. Reproductions of original pre-1800 figures of *Helix laeva*. Fig. 13: lectotype by Martini (1777, Tab. I, p. 416, figs. 8–9). Fig. 14: figures by Chemnitz (1786, Tab. 111), (left) lectotype (Fig. 940) and (right) a shell very similar to the lectotype, Chemnitz Collection (Fig. 941). Note: shells are not shown on the same scale.

DISTRIBUTION. Known only from Roma (Romang) Island, northeast of Timor.

BIOLOGY. Unknown.

Amphidromus (*Syndromus*) *laevus kissuensis* Rolle, 1903

TYPE MATERIAL. Lectotype designated by Zilch 1953 (Laidlaw & Solem, 1961; p. 633), currently in the SM (Malakologie - SMF, 7572), ex. Sig. O. v. Moellendorff collection (ex. H. Rolle); dimensions (see remarks): H 32.64 mm; D 17.77 mm and H/D of 1.84; type locality: Kisar (Kissu) Island, north of the eastern end of Timor Island, Barat Daya Islands (Kepulauan Barat Daya), Southwest Maluku Regency, Maluku Province, Indonesia.

DESCRIPTION OF THE LECTOTYPE. Shell medium (32 mm high), sinistral, obliquely perforate and quite solid. Shape distorted elliptic-pyramidal with a moderately long and tapered spire. Surface is shiny. Macrosculpture: lower teleoconch sporadically marked with growth threads. Microsculpture (as determined from digital images): protoconch almost smooth; teleoconch with numerous growth lines and no discernible spiral microsculpture in the digital images. Whorls about 6½, flatly to moderately convex on the spire; the last is strongly convex opposite the aperture forming a hump (laterally gibbose); base rounded to somewhat flattened and sack-like behind the lip. Coiling is irregular and distinctly distorted by the last whorl's gibbosity and descent toward the lip. Suture shallow, somewhat impressed apically and marked with a thin dull off-white edge. Periostracum absent, worn off or removed (see remarks below). Protoconch is dome-shaped with about 1½ whorls; subtranslucent pinkish brown. Apex obtuse, slightly exsert; black (dark apical spot), extending as an evanescent wedge and same-coloured infrasutural band. Transition to the teleoconch weakly distinguished by a change in whorl convexity and ground opacity. Teleoconch early whorls stained pinkish brown between the brown spiral bands and whitish above; the brown fades-away on the fourth whorl; remaining whorls dirty white.

Pattern combination as per the nominal subspecies, except has different coloured bands. A pale translucent grey weak mora occurs late on the antepenultimate whorl; about 1 mm wide and divides the bands cleanly (see Fig. 22). The band formula for the lectotype as seen on the last half whorl is 12(34)56.

Aperture is oblique, semicircular and about 45% of the shell height. Palatal wall colourless and pellucid, very clearly showing the external bands. Parietal callus is pale straw yellow, very thin and transparent; a small flattened parieto-columellar tubercle present on the parietal callus margin beside the root of the columella. Outer lip white, thickened, narrowly expanded and strongly reflected; external edge rimmed, distinctly so on the basal margin; raised a little above the suture at its termination (ascending termination). Columella white, thickened and wide; straight and oblique, abaperturally angled ventrally and proclined laterally; angular at the columellar-labral junction with its base projecting beyond it (extorted); weakly impressed at its root. Columellar margin wide; dilated above and tapering toward its base; curled over the narrow umbilicus, with its anterior edge distinctly recurved above it. Umbilical interior shows the ground colour of the last whorl, not stained by the circumumbilical band and clearly separate from it.

ANIMAL AND SOFT PARTS. Details unknown.

VARIABILITY. The spire is short to long with a tapered to somewhat turreted (subturreted) profile and the surface may be dull. Protoconch is almost smooth, occasionally with a few microscopic growth threads (microthreads). Teleoconch has a macrosculpture of growth threads throughout, or admixed with ridgelets on the lower whorls; and a microsculpture of numerous microscopic spiral striae (microstriae) overlain by very fine growth lines and microthreads apically, and coarser growth lines elsewhere. Generally, only one mora is present on the penultimate whorl, but commonly a second one may be present on the antepenultimate or previous whorl; and rarely absent or more than two present. The umbilicus is rounded (0.47–1.10 mm wide) or rarely elongated (0.51 x 0.97 to 0.56 x 1.22 mm).

Commonly shells have distorted lower whorls caused by irregular variation in coiling angle and whorl expansion. Distortion either affects just one part of the last whorl like in the lectotype (laterally
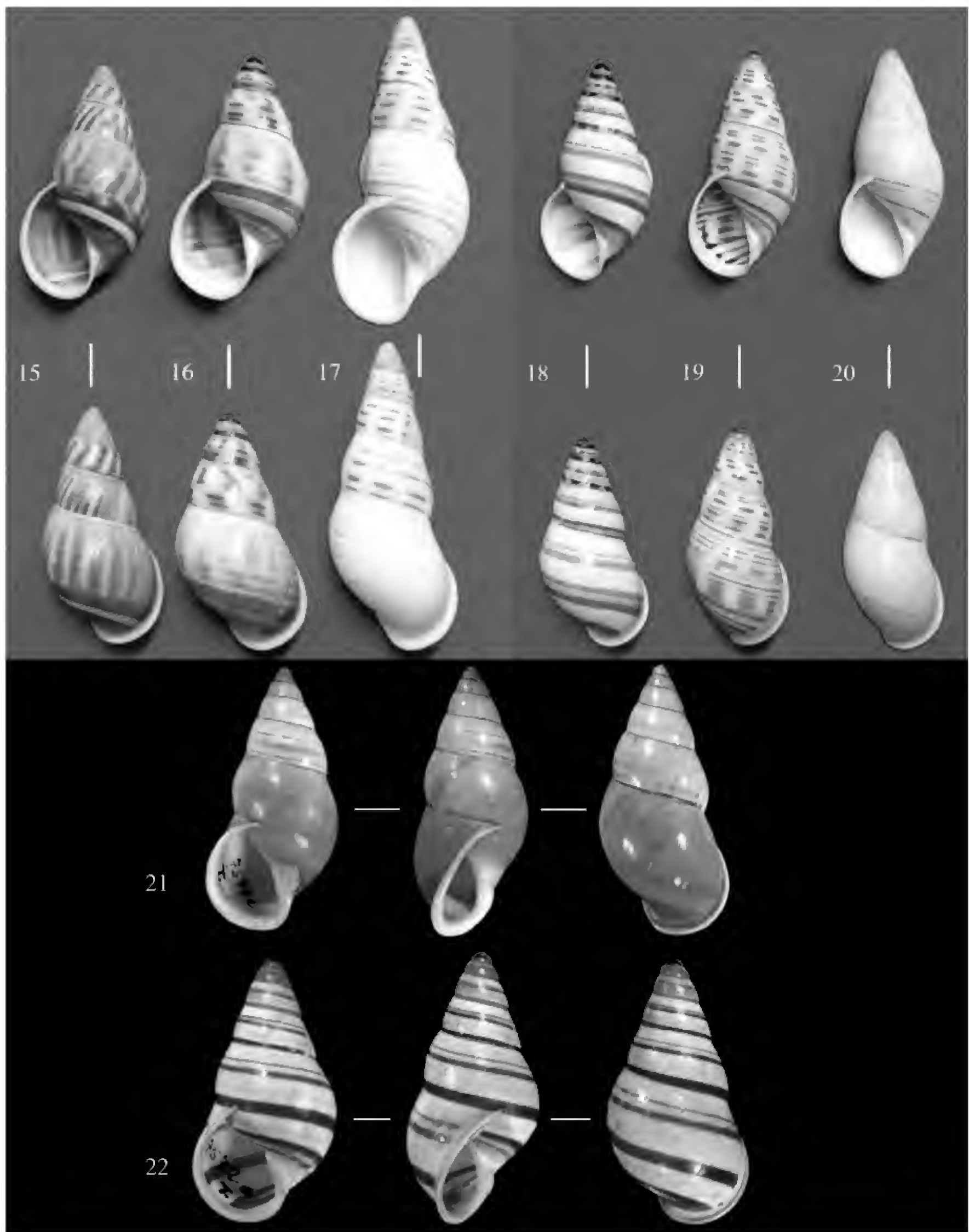
Figures 15–20. *A.* (*S.*) *contrarius nikiensis* from the NikiNiki area, West Timor showing variation of ground colour, pattern, interior, size and shape (JP). Fig. 15: brown flammulated form found closer to the coast and (Figs. 16 to 20) all found close to NikiNiki. Fig. 18: Haniel's *A.* (*S.*) *laevus*'of the literature'. All shells except figure 17 have their periostracum still intact. Note: natural size of shells. Figure 21. Lectotype of *A.* (*S.*) *laevus romaensis*; SMF, Malakologie - SMF, 7574a (a composite of photos 19678-19680,SeSam - Forschungsinstitut Senckenberg 2013). Figure 22. Lectotype of *A.* (*S.*) *laevus kissuensis*; SMF, Malakologie - SMF, 7572 (a composite of photos 19675-19677, SeSam - Forschungsinstitut Senckenberg 2013).

gibbose), or affects both lower whorls (unequally gibbose). Coiling may also be subregular with the last whorl descending toward the lip and little or no distortion of the whorls. The dark apical spot varies as follows: apex to most of the first whorl darkly stained with black fading to brown or reddish purple at its edge; extended as per the lectotype to form a dark apical swirl, fading out toward or on the second whorl, or not extended.

Two distinct colour morphs occur, pallibicinctate and atrifasciate, with the appearance of the dark apical spot and protoconch colour varying between the morphs. Pallibicinctate refers to the two pale coloured bands generally present, one each encircling above and below the periphery. Since these shells lack the dark bands, the band formula is 000000. Atrifasciate refers to shells exhibiting dark coloured bands.

The umbilical interior is clearly separate from and never stained the circumumbilical band when present, and shows only the shell's ground colour. Rarely the teleoconch has a few scattered translucent grey flecks present. A. (S.) laevus kissuensis differs from the other subspecies by commonly having a third overlying band network present consisting of short to long segments of lime green lines superimposed upon the other bands and their interspaces. They appear in both colour morphs only on the last whorl, variable in length, and occasionally very slightly elevated above the shell's surface as spiral ribbons.

DISTRIBUTION. Known only from Kisar, north of Timor.

BIOLOGY. Unknown.

REMARKS. According to Laidlaw & Solem (1961, p. 633) the lectotype was first figured by Zilch (1953, pl. 22, fig. 10). They did not state any measurements of this specimen and incorrectly referred to it as the holotype (p. 633). There is no a scale bar included in the digital images (Fig. 22) in the SMF database (SeSam - Forschungsinstitut Senckenberg, 2013). The SMF classification for this taxon is accepted as A. (S.) laevus kissuensis Rolle, 1903. The shell is clearly marked as being the "type shell" indicated by the letter "T." inside the aperture along with its catalogue number (Fig. 22 centre). The "a" at the end of the catalogue number indicates a second specimen, and according to Rolle (1903) there were two syntypes.

The lectotype is a stocky, primarily white shell with brown bands and two very faded, subobsolete yellow supermedial and submedial bands and the subsutural band is absent. Yet Rolle mentioned black, brown and yellow spiral bands, which suggests the second shell had black bands with more distinct yellow ones. Based on this and after taking measurements from the digital image of the lectotype viewed ventrally (fig. 8 centre), this shell is most likely Rolle's larger syntype, since the calculated measurements closely match his: H 32 mm and D 17 mm. Rolle's second syntype has the dimensions of H 30 mm and D 16.2 mm.

Amphidromus (Syndromus) laevus janetabbasae n. ssp.

TYPE MATERIAL. Number of shells examined: total 25; adult 22 and 3 subadult (very thinly reflected lips); Holotype: AM C.483433; Paratypes: LMA, (LMD/LÖB 133653a-b) (2 shells); AM C.483434 (5 shells); NHMUK 20120339 (4 shells); JAC (2 shells); JP (11 shells); dimensions: H 33.91 mm; D 17.21 mm; and H/D of 1.97; type locality: Moa Island, north-northeast of Timor Island, Southwest Maluku Regency, Malaku Province, Indonesia; found in villagers' plantations and the forest bordering them, on the eastern side of the road between the foothills to the north of Wakarlili on the southwest coast (Fig. 1).

OTHER MATERIAL. JA: from the type locality; 49 adult shells.

DESCRIPTION OF THE HOLOTYPE. Shell medium (33.91 mm high), sinistral, obliquely perforate and moderately solid. Shape ovate-conic with a moderately long spire, profile somewhat flattened; H/D ratio of 1.97. Surface is glossy; protoconch smoothish; teleoconch macrosculpture of growth threads on the lower whorls and occasional ridgelets on the last whorl; and teleoconch microsculpture of numerous spiral microstriae overlain by thin growth lines throughout and occasional microthreads apically. Whorls 6¼, slightly or moderately convex; a small section is a little swollen (subgibbose) just after the mora; base angularly rounded. Coiling is subregular, faintly distorting the lower whorls; last whorl descending toward the lip. Suture impressed apically, shallow below; bordered by a faint to bold white

marginal line. Periostracum removed in the holotype (see remarks below). Protoconch is rotund with about 1½ whorls; opaque cream infrasutural band is faint; ground subtranslucent pink; apex blunt, a little exsert. Apical spot pale, not blackened; whole apex opaque whitish. Transition to the teleoconch weakly distinguished by several microthreads.

Teleoconch ground stained pink apically, fading-away on the third whorl; remaining whorls whitish grading to yellow on the last; variously marked with pale, medium or dark coloured spiral bands, emerging on the second and third whorls forming a pattern combination as per the nominal subspecies, except more vividly coloured. A single translucent pale grey mora is present roughly mid-penultimate whorl; 1 mm wide, each side bordered by an opaque greyish resting line; it marks a rapid change in band colour and appearance (see Fig. 23). The holotype has the band formula of 123456.

Aperture is oblique with a perch angle of 19°; subovate and anteriorly subangular; AH/H ratio of 0.48. Umbilical interior white; moderately calcified and translucent, clearly showing the dark external bands. Parietal callus colourless; faintly calcified and imperceptible; a minute parieto-columellar tubercle present at the junction with the columella, fading as a curved trace along the parietal callus margin; and a minute parieto-labral tubercle adjoins the outer lip's termination. Outer lip has a white face and faded pale yellow inner margin with faded pale purple stains at both ends; thin, strongly reflected and narrowly expanded; face and external edge flat; posterior termination slightly ascending. Columella white; thickened, narrow and straight; oblique and abaperturally angled (9°) ventrally; subvertical and proclined laterally; angular at the columellar-labral junction with a slightly excurved base. Columellar margin white; curled over the umbilicus, partially covering it; face convex; cylindrically dilated, its base tapered. Umbilicus is round and narrow, 0.93 mm wide. Inner umbilicus tinged by the circumumbilical band.

ANIMAL AND SOFT PARTS. Unknown as all specimens were collected by locals for Mr. John Abbas and received as empty shells.

VARIABILITY. Shells are variable in shape, commonly ovate-conic, but also oblong (like that of *A. (S.) latestrigatus* Schepman, 1892) to elongate-tapering when distorted.

This species is very variable in the morphology of the aperture, palatal wall, outer lip, columella, columellar margin and base. The umbilical interior is very rarely yellow.

A well-developed parieto-columellar tubercle is generally a trace line or absent; uncommonly occurs as a thin curved line of callus in mature shells; and rarely a short smudge at the root of the columella.

A parieto-labral tubercle adjoined to the lip termination is rarely present, either a minute lump (as in the holotype) or an elongate lump a few millimetres long. The umbilicus is rounded and large for the group (0.66–1.84 mm wide) and rarely elongated (0.92 x 1.14 to 0. 53 x 1.14 mm).

Faintly distorted subgibbose shells have less pronounced swelling of the lower whorls than *A. (S.) laevus kissuensis*. However, the subregular coiling in these shells causes a steeper descent angle of the last whorl, creating an appearance of greater distortion. Rarely true longitudinal distortion does occur (2 shells) where irregular coiling elongates the last whorl positioning it well below the periphery, thus exposing more of the previous whorl than usual. Coiling may also be regular or subgibbose without distorted whorls. Atrifasciate shells are the predominant form on Moa, with pallibicinctate shells being rare. Both morphs have a similar disparity in the colouration of the early whorls seen in *A. (S.) laevus kissuensis*.

In atrifasciate shells, the supermedial and submedial bands may brown, blacken or redden toward a mora and/or the lip, and the subsutural band rarely develops a brown tinge. The most constant band formulas are 020450 and 023450. All six bands are commonly present and rarely are five or all six partially absent on the last whorl, usually ventrally. The less common band formula of 000450 is comparable with two variations of *A. (S.) contrarius* Müller, 1774. The pure form of 000450 with bands 1 to 3 absent on the spire is quite rare. Commonly shells have other one or more bands on the spire that are lost randomly or after a mora and do not reappear on the last whorl. *A. (S.) contrarius* var. *suspectus* von Martens, 1864 displays pomegranate supermedial and submedial bands and the dark band formula of 000450, and rarely have bands 1 to 3 present on the uppermost whorls. *A. (S.) contrarius* var. *albolabiatus* Fulton, 1896 has only the pure form of 000450 and lacks the first network bands.

The external appearance of the lower whorls shows a wider range of shell colours created by the combination of periostracum, band and ground colour. The colour of the protoconch and first network bands is very variable. A variable dark apical spot is present or absent. A mora either marks a hiatus in the banding without modification of colour and/or pattern, or marks a rapid change. Additional shell pattern elements consist of dilution streaks and/or shadowy deepening streaks, usually on the last whorl.

DISTRIBUTION. Based on current material available, this subspecies is currently known only from type locality; it appears to be restricted to Moa, possibly found in the same vegetation type over the whole of the island.

BIOLOGY. Found on the leaves, limbs and branches of small trees and trunks of larger trees in deciduous broadleaf forest and villagers' plantations.

ETYMOLOGY. Named in honour of Mr. John Abbas' daughter Janet.

REMARKS. The holotype's minute parieto-labral tubercle is comparable to that of the nominal subspecies. Its labral inner margin stains are due to pigment leaked from the outer surface ground and bands. Its lip is thinner than average, but equal in thickness to a well-thickened lip seen in *A. (S.) contrarius* (s.s.). The periostracum when present covers only the lower whorls: thin, pellucid, dull; pale yellow to ochre; occasionally with darker or paler streaks toward the lip. These streaks tend to appear above the dilution or deepening streaks on the shell, which dilute or deepen the ground and pattern colour respectively. *A. (S.) kruijti* P. et F. Sarasin, 1899 has similar periostracal streaks. The parietal callus is colourless in fresh specimens, but becomes whitish and deteriorates in older empty collected shells.

The pale purple inner labral stains are comparable to those of other species. *A. (S.) kuehni* Moellendorff, 1902 has ruddy anterior and posterior stains (prominent externally, faded internally), and any faint yellow staining is from an external preapertural band showing through. In *A. (S.) annae* von Martens, 1891 the entire outer margin is reddish purple (claret when dark, or magenta when pale), across at least the lower lip face and sometimes faintly along the inner margin, with the deeper tones shining through to the outside. Shells are

excessively variable in colouring and banding, but commonly like that of the holotype. Compared to *A. (S.) laevus kissuensis* the supermedial and submedial bands are never obsolescent on the spire, but may appear faintly darker than the yellow or pale saffron ground of the last whorl. Inner wall is the preferred term to describe the exterior surface of the previous whorl inside the aperture.

The translucent flecks are generally greyish, rarely brownish, and sometimes have a same-coloured shadow. These particular flecks are comparable to a translucent brownish fleck and creamy shadow on *A. (S.)* cf. *laevus* from Tutuala; and the comet like markings of a black dot and yellow tail on *A. (S.) coeruleus* Clench et Archer, 1932.

Amphidromus (Syndromus) laevus nusleti n. ssp.

TYPE MATERIAL. Number of shells examined: total 15 (adult); Holotype: AM C.483435; Paratypes: LMA, LMD/LÖB 133654a-b (2 shells); AM C.483436 (2 shells); NHMUK 20130070 (2 shells); JAC (2 shells); JP (6 shells); dimensions: H 32.33 mm; D 17.62 mm; and H/D of 1.83; type locality: Leti Island, north-northeast of Timor Island, Southwest Maluku Regency, Malaku Province, Indonesia; found in forest on the hills to the south of Sewaru village, which is on the northern coastline of the island near Cape Tutukei (Fig. 1).

OTHER MATERIAL. JP: 4 adult shells; 2 from the type locality and 2 from forest behind the beach near Cape Tutukei and Sewaru village. JA: from the type locality; 1) 27 adult and 2 juvenile non-atrifasciate shells; 2) 17 adult atrifasciate shells; 3) 6 adult mid-banded shells

DESCRIPTION OF THE HOLOTYPE. Shell medium sized (32.33 mm high), sinistral, obliquely perforate and heavily calcified. Shape ovate-conic; H/D ratio of 1.83. Spire moderately long and subturreted. Surface glossy; protoconch smoothish; teleoconch macrosculpture of growth threads on the lower whorls, and the last whorl also has numerous ridgelets and a varix and teleoconch microsculpture of crowded spiral microstriae crossed by growth lines and microthreads. Whorls 6; convex and gradually expanding; base angularly rounded becoming flattened behind the lip. Coiling is subregular; last whorl descends toward the varix and horizontal there-

after. Suture impressed apically and shallow on following whorls; bordered by a white marginal line. Periostracum removed in the holotype (see remarks below). Protoconch dome-shaped with steep sides, 1½ whorls; ground translucent pink; apex subangular, obtusely pointed and a little exsert. Apical spot dark; most of the first whorl stained black, becoming reddish purple marginally; extended along the sutural margin as a thin dark apical swirl, fading out on the second whorl. Transition to the teleoconch weakly demarcated by several microthreads. Teleoconch ground stained pink apically; second whorl whitened; fourth whorl stained very pale straw yellow, grading to saffron toward the varix and faded after it.

Pattern of spiral bands formed as per the nominal subspecies, but differently coloured and modified (see Fig. 24). The holotype has two incomplete bands and so a formula of 0::450.

Aperture is oblique, subovate and posteriorly rounded; perch angle 24° and AH/H ratio 0.49. Aperture interior thickly calcified, subopaque; whitish, a little glossy; external bands weakly visible, unmodified in colour. Parietal callus colourless; faintly calcified and inconspicuous; parieto-columellar tubercle is a small lump adjoined to the end of the columella margin's flange; parieto-labral tubercle is elongate, about 1 mm long. Outer lip white; moderately thickened, strongly reflected and moderately expanded; face flat; lower half of outer edge rimmed; posterior termination ascending a little. Columella white, thick and broad, a little twisted; subvertical and abaperturally angled (5°) ventrally; oblique and proclined laterally; angular at the columellar-labral junction, its base extorted. Columellar margin is white; jutted over the umbilicus, partially covering it; face convex and well thickened, forming a flange extending to its insertion point; cylindrically dilated and its base obliquely truncate with a subangular jut. Umbilicus is round and narrow, 1.08 mm wide. Umbilical interior partially tinged by the circumumbilical band.

VARIABILITY. Whorls are flattened to convex; sometimes the lower whorls are weakly to moderately swollen (subgibbose to gibbose), or just the last whorl is ventricose. Coiling is regular; subregular with the last whorl descending toward the lip; or irregular with the lower whorls unequally gibbose and faintly to distinctly distorted. Spire short

to long with a somewhat flattened to subturreted profile. Sculpture as per the holotype or a little rough locally, with occasional ridges or growth welts commonly on the last whorl, sometimes on the penultimate whorl and rarely on the upper whorls. The umbilicus is round, narrow to moderately wide (0.54–1.34 mm) and rarely elongate to rimate (0.65 x 1.18 to 0.35 x 1.10 mm). Umbilical interior always tinged by the circumumbilical band. Sometimes a single whorl forms the protoconch. Dark apical spot is large as per the holotype; or small with only the tip to whole apex stained black, extending outward a little while fading to brown or reddish purple at its edge.

Additional shell pattern elements consist of dilution or deepening streaks, sometimes the latter are browned or blackened on the last half whorl; and the teleoconch is rarely marked with translucent grey or brownish flecks. Resting lines are generally a growth stria, but sometimes form a ridgelet or swell up into a wide ridge formed from a former lip (true varix). On Leti, pallibicinctate shells are the predominant form, atrifasciate shells are uncommon and mid-banded shells are rare. There is a greater disparity in the colouration and form of the pallibicinctate and atrifasciate shells than that seen in *A. (S.) laevus janetabbasae* n. ssp. and *A. (S.) laevus kissuensis*. All three of these colour morphs may have the first network bands browned or blackened toward a mora and/or the lip, rarely reddened beforehand. The supermedial and submedial bands often appear faintly darker than or fade into the yellow or saffron ground of the last whorl.

A few shells have 6, 7 or 8 dark bands, but extra bands inserted into the pattern created these combinations. Only a single shell has the 000450 pattern with bands 2 and 3 on the upper whorls, a pattern more commonly seen in *A. (S.) laevus janetabbasae* n. ssp. Counting extra dark bands inserted into the pattern, a maximum number of 12 and minimum of 4 on the last whorl (subsutural, supermedial, submedial, and circumumbilical) bands present.

ANIMAL AND SOFT PARTS. Unknown as all specimens were collected by locals for Mr. John Abbas and received as empty shells.

DISTRIBUTION. Based on current material available, this subspecies appears to be restricted to Leti

and probably found in the same vegetation type over the whole of the island, including behind the beaches.

BIOLOGY. Found on the leaves, limbs and branches of small trees and trunks of larger trees in deciduous broadleaf forest and vine thickets.

ETYMOLOGY. The subspecies epithet is derived from Nusleti, a historical Letinese name of Leti Island (van Engelenhoven, 1997) and used here as a noun in apposition.

REMARKS. The holotype represents the average conchological features of the subspecies, and the average banding modification and pattern seen in the atrifasciate shells. It also has a true varix that occasionally develops in this subspecies. Its slate-coloured dark bands are not present in the other populations. Its parieto-labral tubercle is at full development for the subspecies. It has the following similarities with *A. (S.) laevus janetabbasae* n. ssp.: columella and its margin are similarly formed; parieto-labral tubercle is equal at full development; and aperture is similar in shape. However, *A. (S.) laevus nusleti* n. ssp. tends to have an angular jut at the base of the columellar margin; parieto-columellar tubercle is a small lump or short ridge and never fades as a curved trace or forms a long ridge; and outer lip is opaque white with a flat or rimmed edge. Periostracum covers only the lower whorls when present: thin, pellucid, dull; and pale yellow to citron-ochre; sometimes with darker periostracal streaks towards the lip as in *A. (S.) laevus janetabbasae* n. ssp.

Pallibicinctate shells may have no translucent grey morae present, or commonly have one or two present, 0.5–3 mm marked by an opaque resting line, and sometimes followed by a narrow whitish or yellowish post-marginal band. Occasionally wider multiple zones occur, composed of multiple very thin morae. One non-type shell has several deepening streaks stained with a reddish brown hue on the last half whorl. Overall these more or less yellow shells are comparable to *A. (S.) contrarius* var. *subconcolor* von Martens 1867, a nearly uniform yellowish white shell with two very faint yellow bands encircling the last whorl. However, it differs in the last whorl being darker yellow toward the base and faded above; and it has the same parietal tubercles and outer lip features as per *A. (S.) contrarius* (s.s.).

This subspecies also shows a rare intermediate form (6 shells), which shares features of both of the other two forms thus proving they are only colour morphs. These shells have a single very thin to thick dark, brown or blackish band at the periphery (mid-banded shells). The band is seen at the suture on the spire or not (1 shell). The band is absent on the last whorl in one shell, evanescent in another and faint to bold in the other four shells.

Compared to *A. (S.) laevus kissuensis* and *A. (S.) laevus janetabbasae* n. ssp. the band patterns are extremely variable and more randomly developed; and partial bands are quite common, either incomplete or evanescent. The atrifasciate shells have less variation in band colour combinations than those of *A. (S.) laevus janetabbasae* n. ssp., but there is greater colour variation in the ground and bands in its pallibicinctate shells. Compared to all the other subspecies, on average, this subspecies has a wider apex and a shorter spire for the same spire width; therefore, it has a greater spire angle. Partially interrupted bands caused by dilution streaks, tend to occur on the spire rather than on the last whorl. Such interruptions occur behind the lip on the only shell seen with all six bands present. The formation of the superior band and two-toned peripheral band is as follows: all three bands are brown on the second whorl, changing to slate on the third whorl; fade late on the penultimate whorl; and then deepen again early on the last whorl. On the fourth whorl, the space between bands 3 and 4 becomes grey, thus forming a two-toned band with a pale grey central zone, with the whole band intermittently faded.

DISCUSSION

Compared to the *A. (S.) contrarius* subspecies, the *A. (S.) laevus* subspecies differ by the supermedial and submedial bands displaying hues other than yellow; the submedial bands lack a same-coloured zone suffused over them; and the lack of axial or oblique flammules divided or not by a de-coloured (i.e. of the ground colour, whitish) or yellow supermedial band. In addition, the parieto-columellar tubercle is variably developed among the subspecies, never shelf-like; the lip termination is fused to the body whorl and the parieto-labral tubercle when present (minute or elongate

lump), so no gaps; and no canal beneath the suture inside the aperture. They also lack a pinkish brown medial zone between the bands of the superior and peripheral band pairs seen in the maculated zones of the *laevus*-like shells (Fig. 18). They may also display post-mora modification of pattern elements, also seen in *A. (S.) contrarius hanieli* Rensch, 1931 (and in *A. (S.) reflexilabris hanielanus* Rensch, 1931).

Even though some *A. (S.) contrarius nikiensis* shells have a similar colouration and band pattern (*laevus*-like shells figure 18) to the lectotype of *A. (S.) laevus laevus*, the latter has greater links to its subspecies. The data in Table 1 clearly show this, where all shell measurements are similar and no particular subspecies has anything outstanding dimensional features. However, some distinctive features can be noted: *A. (S.) laevus janetabbasae* n. ssp.
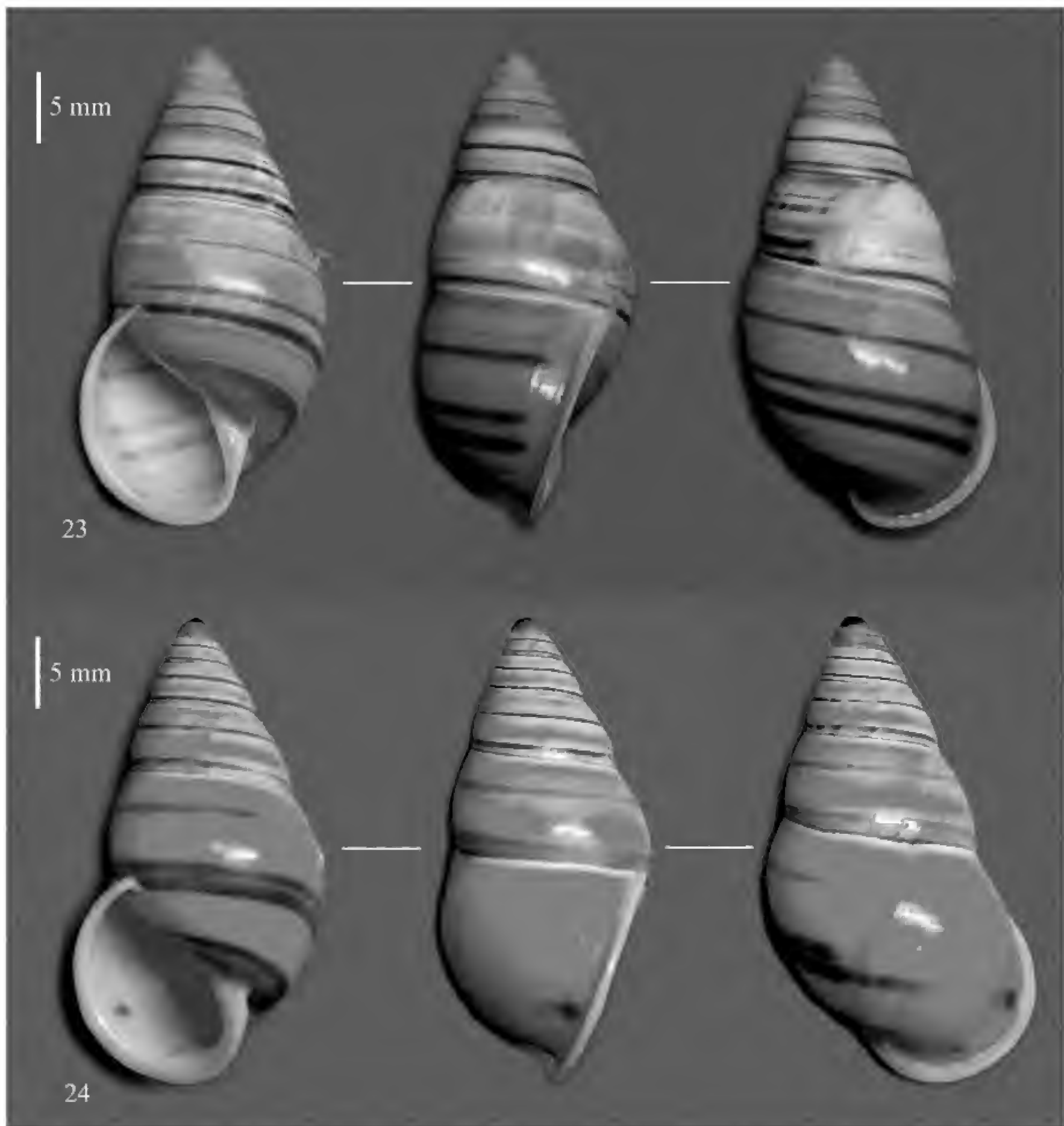
Figure 23. Holotype of *Amphidromus (Syndromus) laevus janetabbasae* n. ssp.
Figure 24. Holotype of *A. (S.) laevus nusleti* n. ssp.

has a larger umbilicus; *A. (S.) laevus kissuensis* has a smaller aperture for the same sized shell; and on average *A. (S.) laevus nusleti* n. ssp. has the least number of whorls, a lower H/D ratio and smaller shells, with the largest shells coming from Moa, Roma and Tutuala. All subspecies have a AH/H ratio less than 0.5, plus similar columellar and perch angles.

The Kisar, Roma and Tutuala populations all have a rimmed lip, which is a distinctly reflected edge. For *A. (S.) laevus nusleti* n. ssp. the lip edge is variably flat or rimmed, with the degree of reflection dependant on lip maturity. In *A. (S.) laevus janetabbasae* n. ssp., only a few gerontic shells with greatly thickened lips have a weakly rimmed edge. The shape, colouration and pattern similarities of shells from Tutuala, Roma and Leti Islands (Leti, Moa and Lakor) suggest they originated from a common population. The *A. (S.) laevus romaensis* lectotype shows a great similarity in shape and pattern modification to some shells of *A. (S.) laevus janetabbasae* n. ssp., and the lack of a dark apex. But it has a stronger posterior lip curvature and a wide flattened parieto-columellar tubercle compared to *A. (S.) laevus janetabbasae* n. ssp., which has a thin curved line of callus (rarely a short smudge) and a more angular aperture. The same tubercle in *A. (S.) laevus nusleti* n. ssp. is short and thick, and a small-flattened lump in *A. (S.) laevus kissuensis*.

A. (S.) laevus kissuensis appears to have developed from a separate population to the other subspecies, differing in several features. Most shells have a whitish ground and the atrifasciate shells rarely having a yellow last whorl. The subsutural band when present is only ever yellow, of the same hue as the supermedial and submedial bands. The most distinctive feature is both colour morphs may display a third band network of lime green lines on the last whorl, something not seen in the other populations studied. The closest ties are between the subspecies from Leti and Moa, isolated only by a narrow sea channel. However, on Leti there is a predominance of the pallibicinctate shells compared to a scarcity on Moa. This suggests isolation was not only by a physical barrier but also by niche preference. Pallibicinctate shells prefer the drier and more open thorn forests on Leti, while atrifasciate shells prefer more shaded forests with a less open canopy on both islands.

Pallibicinctate shells of the above three subspecies are easily distinguishable. On Kisar, they are uncommon white shells with two or three yellow bands, often obsolescent with some shells grading to almost pure white; and may have lime green lines. Rare on Moa, shells with the last two whorls pale yellow, plus two or three pale to dark yellow bands, one or both may be partially tinged orange. Common shells on Leti, with the last two or three whorls of various yellow hues or grade to saffron; plus two or three pale to dark yellow or orange bands, often partially browned or blackened and rarely partially reddened. Sometimes the subsutural band is of different colour (rose or reddish orange) to the other two bands; and rarely has a narrow rose circumumbilical band (3 shells).

After a mora or growth flaw, atrifasciate shells of *A. (S.) laevus janetabbasae* n. ssp. commonly show a patchy loss and colour change (pied forms), or distinct and rapid colour change. The unmodified dark bands tend to be black or rarely brown. In the atrifasciate shells of *A. (S.) laevus nusleti* n. ssp. studied, unmodified dark bands are black, sooty, blackish brown, brown or slate; and band modification may occur before or after a mora, or occur randomly and gradually without a mora present. A single pied form from Leti has only the dark bands partially absent, which return changed to pink toward the lip. Both subspecies have a narrow to wide circumumbilical band that rarely fails to enter the umbilical interior, and the inner labral margin may have coloured stains, also seen in shells from Lakor. Either the purplish anterior stain is dominant and fades-away as the lip thickens (Lakor and Leti), or the longer yellow lateral stain is dominant and weak at maturity (Moa). Similar yellow staining seen in shells from Tutuala is in fact a preapertural band showing through from the outside.

A. (S.) laevus janetabbasae n. ssp. and *A. (S.) laevus nusleti* n. ssp. may have streaks that dilute or deepen the band and ground pigment, often faint or become distinct toward the lip. The Tutuala population has these too, and dilution streaks sometimes faintly or distinctly interrupt the bands on the spire. This happens in the other two subspecies too, but only as short sections of affected bands. Random partial dilution and deletion also forms interrupted bands. Dilution streaks often disturb the coloured suffusion on the last whorl, bleaching it thus showing an undertone (discussed below).

The medial zone of two-toned bands may suffer intermittent dilution, thus forming maculated zones of pale and dark blotches with dark borders. These maculated zones generally occur on the spire and are either short with weak randomly spaced small blotches (Leti and Moa), or long with wider alternating blotches (Tutuala).

The first network bands may develop brown or black staining toward a mora and/or the lip in both colour morphs of *A.* (*S.*) *laevus nusleti* n. ssp. In atrifasciate shells of *A.* (*S.*) *laevus janetabbasae* n. ssp., only the supermedial and submedial bands have the same staining, commonly reddened too, and it rarely affects the subsutural band. *A.* (*S.*) *laevus* (s.s.) shows a similar feature, except the same bands are firstly invisible and then emerge on the last whorl stained brown. Only in *A.* (*S.*) *laevus janetabbasae* n. ssp. are these bands completely bleached to white after a mora and develop thin red or blackish borders. These band modifications are absent in the other populations. The subsutural band when present is generally the same colour as the other two bands in pallibicinctate shells, and commonly different in atrifasciate shells (magenta, red or rose).

Distortion of the lower whorls is similar in shells from Tutuala, Leti and Kisar, although the latter have more gibbose whorls. *A.* (*S.*) *laevus janetabbasae* n. ssp. tends to have elongated distortion from a greater change in the coiling angle. A weakly developed shoulder and/or an obsoletely subangular periphery on the last whorl may exaggerate distortion in *A.* (*S.*) *laevus nusleti* n. ssp.; a dark apical spot is always present in *A.* (*S.*) *laevus kissuensis*; very rarely absent in *A.* (*S.*) *laevus nusleti* n. sp. with only one shell known; present or absent in shells from Tutuala, Moa and Lakor; and absent in *A.* (*S.*) *laevus* (s.s.) and *A.* (*S.*) *laevus romaensis*. Development of parietal tubercles varies among the subspecies, often absent or at least very weakly developed. A parieto-labral tubercle occasionally occurs in some shells from three populations: a minute lump (*A.* (*S.*) *laevus* (s.s.), Leti and Moa) or a small elongate lump perpendicular to the lip (Leti and Moa), and the latter is seen in some shells of *A.* (*S.*) *sinistralis* Reeve, 1849 and *A.* (*S.*) *centrocelebensis* Bollinger, 1918.

A parieto-columellar tubercle develops into one of four forms. The following is a comparison of *A.* (*S.*) *laevus* subspecies (locality of each is in brack-

ets) with other species that also develop each one of these. *A.* (*S.*) *latestrigatus* has a flattened lump (Kisar, Roma, Moa and Leti), except it is reddish purple. *A.* (*S.*) *beccarii* Tapporone-Canefri, 1883 and *A.* (*S.*) *annae* have a faint trace or long thin line (Moa). A long narrow ridge (Moa and Tutuala) forms in *A.* (*S.*) *centrocelebensis* and *A.* (*S.*) *contrarius* (s.s.) (moderately developed). Lastly, a short narrow ridge (Leti) develops in *A.* (*S.*) *maculatus* Fulton, 1896 and *A.* (*S.*) *kuehni*. The same callosity when well developed in *A.* (*S.*) *contrarius* (s.s.) is like a ledge jutting out from the inner wall. Even this looks feeble compared to the ridge developed in *A.* (*S.*) *sinistralis*, which can be 1 to 2.5 mm thick rising to the same plane as the outer lip and appear as an extension of the columella.

Generally, *A.* (*S.*) *laevus kissuensis* has a white last whorl, rarely medium yellow. The other populations have various yellow tones on the last half to the lowest three whorls. Atrifasciate shells from Tutuala show the greatest variation of the last whorl colouration, due to band pigment leakage suffusing across the whorl or as localised spiral zones. This suffusion is pink, magenta, purple, brown or greyish green, with an undertone of cream or yellow. *A.* (*S.*) *laevus janetabbasae* n. ssp. may have a pink suffused last whorl and a yellow undertone, or as pink, brown or pale reddish orange spiral or longitudinal suffusion zones. *A.* (*S.*) *laevus nusleti* n. ssp. shows only pink spiral suffusion zones.

According to Taylor (1914), an abrupt change in pigment colour can be due to a change in diet. Taylor also says if pigment-secreting cells are latent or undeveloped during early shell development, bands gradually or suddenly develop at the commencement of a growth period, or they show atrophy at the termination of a growth period that causes the partial or complete loss of bands during regrowth. This describes quite well some of the variation seen in the *A.* (*S.*) *laevus* group. However, the atrophy of the pigment-secreting cells may occasionally be a gradual process with the bands slowly fading-away. Taylor (1914) also discusses links for banding variation in *Theba pisana* Müller, 1774. He says in exposed habitats shells tend to have delicate linear banding that tends to be irregularly developed, while in less open and more shaded habitats shells have more distinct and better developed banding. This applies well with the banding of the *A.* (*S.*) *laevus* group, with the addition of the palli-

bicinctate shells being a form possibly adapted for exposed habitats.

Addition pertains to extra bands inserted into the pattern, not split from the main pattern bands, and occur as either short or long segments (partial bands). Division applies to main pattern bands that split into narrower bands or lines (bandlets). Width variation simply refers to different shells having either thin or thick bands, or in combination. Fusion ascribes adjacent bands gradually widening during development and connect to form wider bands. If fused bands dilate as well, then many bands may connect behind the lip to form a partially very dark shell (pseudomelanism). Spreading is band pigment leaked into the interspaces as stains, short streaks or connection of adjacent bands (two-toned bands), and widespread or zoned suffusion. Pigmentation variation involves intermittent fading of band and/or ground colour, occurring faintly along growth lines or wider marks along bands that may grade to maculated zones or even interrupted bands. In comparison, dilution and deepening streaks are pattern elements that modify the shell pigments more strongly. Reduction refers to indistinctly or irregularly developed bands, which are partially faded and those that gradually fade (evanesce) or gradually narrow before vanishing. Results of studies on other banded snails suggest that the banding pattern is probably under genetic control in this species as well.

The *A. (S.) laevus* group have another four types of pigmentation variation. Firstly, incomplete xanthism relates to the pallibicinctate shells where the yellow or orange bands are imperceptible on a same-coloured last whorl (Leti); and similarly coloured shells that have dark bands on the upper whorls (Tutuala). Incomplete albinism applies to almost pure white shells with very faint or obsolescent supermedial and submedial bands (Kisar); and shells with dark banded upper whorls and pure white lower whorls lacking first network bands (Tutuala). Partial leucism refers to the pied forms with short to long patch-like modification of some to all bands after a mora (Moa and Roma). It affects band colouration and presence, rarely affecting ground colour (Roma). No juvenile shells were available to show the pied modification affects bands on the base. Lastly, selective leucism pertains to the discolouration or dilution of band pigment without affecting the ground colour, for

at least part of the shell (Kisar, Leti, Moa and Tutuala). For example, the bands change from brownish to pinkish or from blackish to purplish, usually abruptly or gradually after a mora, less often randomly on the shell.

Overall the subspecies may share certain conchological features (e.g. weakly to distinctly abaperturally angled and/or proclined columella), but local modifications of others (e.g. parietal tubercles and sculpture) can be used to separate them in mature shells.

CONCLUSIONS

In their isolation, each island population of *A. (S.) laevus* has developed localised variations in shell pattern and minor differences in shell characters not found in other populations. Differences include, but are not limited to: apex colouration (black or dark apical spot, present or absent); colouration of the protoconch and lower whorls; thickness and reflection of the lip and columella; surface sculpture; and the development of parietal callosities. Variation in the banding occurs via a number of modifications, in terms of: addition, division, width variation, fusion, spreading, pigmentation variation, reduction, plus genetic control of the number of bands present.

Collectively these variations have developed a number of different subspecies, and the whole intension of this study was to show that. All of the above points show that the subspecies of *A. (S.) laevus* are a group of snails that are highly polymorphic in their shell colour and banding. This is especially the case for the Tutuala population. Due to the lack of study material, this study was unable to determine if shells like that of the *A. (S.) laevus laevus* lectotype occur on Lakor or at Tutuala. Further research is required to determine if they are separate subspecies. Knowledge of the conchological features and distinctive phenotypes created by local pattern variation, allows the subspecies to be distinguished in a mixed sample.

ACKNOWLEDGMENTS

for photos of shells in his collection. I owe a debt of gratitude to the following people: Danny Eibye-Jacobsen, Assoc. Prof., Curator (of the mollusc collection) and Tom Schiøtte for photos (ZMUC); Dr. Mandy Reid, Malacology Collection Manager for assistance in depositing type material (AM); Jonathan Ablett, Curator (of Non-Marine Mollusca and Cephalopoda, Division of Invertebrates, Zoology Department) for assistance in depositing type material and their photographic unit for photos (NHMUK); and Dr. Silke Stoll, Curator (of the mollusc collection) for assistance in depositing type material and photos (LMA).

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A new species of *Agrilus* Curtis, 1825 from Brazil (Coleoptera Buprestidae)

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ABSTRACT   A research of Museu de Entomologia da FEIS/UNESP, campus de Ilha Solteira, São Paulo (SP) region, Brazil (MEFEIS) in order to monitoring the secondary xylophagous species, showed the presence of a new species of *Agrilus* Curtis, 1825 (Coleoptera Buprestidae) that is here described: *Agrilus* (*Agrilus*) *flechtmanni* n. sp.

INTRODUCTION

A staff of the departement of Entomology of FEIS/UNESP (Universitade Estadual Paulista, Campus de Ilha Solteira, Brazil), made a research for studying the biology of secondary xylophagous insects.

Some species of Neotropical Coleoptera Cerambycidae (Serville, 1835), manly belonging to the genus *Oncideres* Serville, 1835 (Lamiinae) attack tree species girdling the branches with the aims of interrupting the lymphatics vessels and killing the apical part where the larva will live (Fig. 1). Some wood-boring secondary species develop in those branches, taking advantage of the particular habitat. Particularly favoured are obviously small species that are able to colonize the restant space made available by the primary host.

Oncideres species burrow large galleries in the wood, leaving intact the bark only, and the species specialized to colonize the remainder of the branch are generally small and mainly sub-corticicolous. Particularly favoured are some monovoltine species

of the genus *Agrilus* Curtis, 1825. The girdled branches are weak and liable to breakage so they are often found at the base of the trees, where they were collected and placed in breeding containers, waiting for the adults to emerge.

In the course of this research we obtained some specimens of a new species of *Agrilus* (Curtis, 1825) that is described here.

MATERIAL AND METHODS

The study area is in Brazil, São Paulo (SP) region (Fig. 2). The specimens were provisionally stored in formaldehyde, followed by dry preparation and glued on a card for the study and description and conservation.

The genitalia were placed on the same card.

The pictures were made with a Coolpix P6000 connected with a stereomicroscope Leica MZ6, elaborated with Adobe Photoshop CS5 Extended vers. 12.0 and stacked with Combine Z4 program.

Figure 1. Branch girdled by *Oncideres* sp. (Coleoptera Cerambycidae), French Guyana (photo S. Brûlé).

Figure 2. Study area: Brazil, São Paulo (SP) region, locality of the new species of *Agrilus*.

ABBREVIATIONS. MEFEIS = Museu de Entomologia da FEIS/UNESP, campus de Ilha Solteira; São Paulo (SP), Brazil. MCCI = Museo Civico di Storia Naturale di Carmagnola, Torino, Italy.

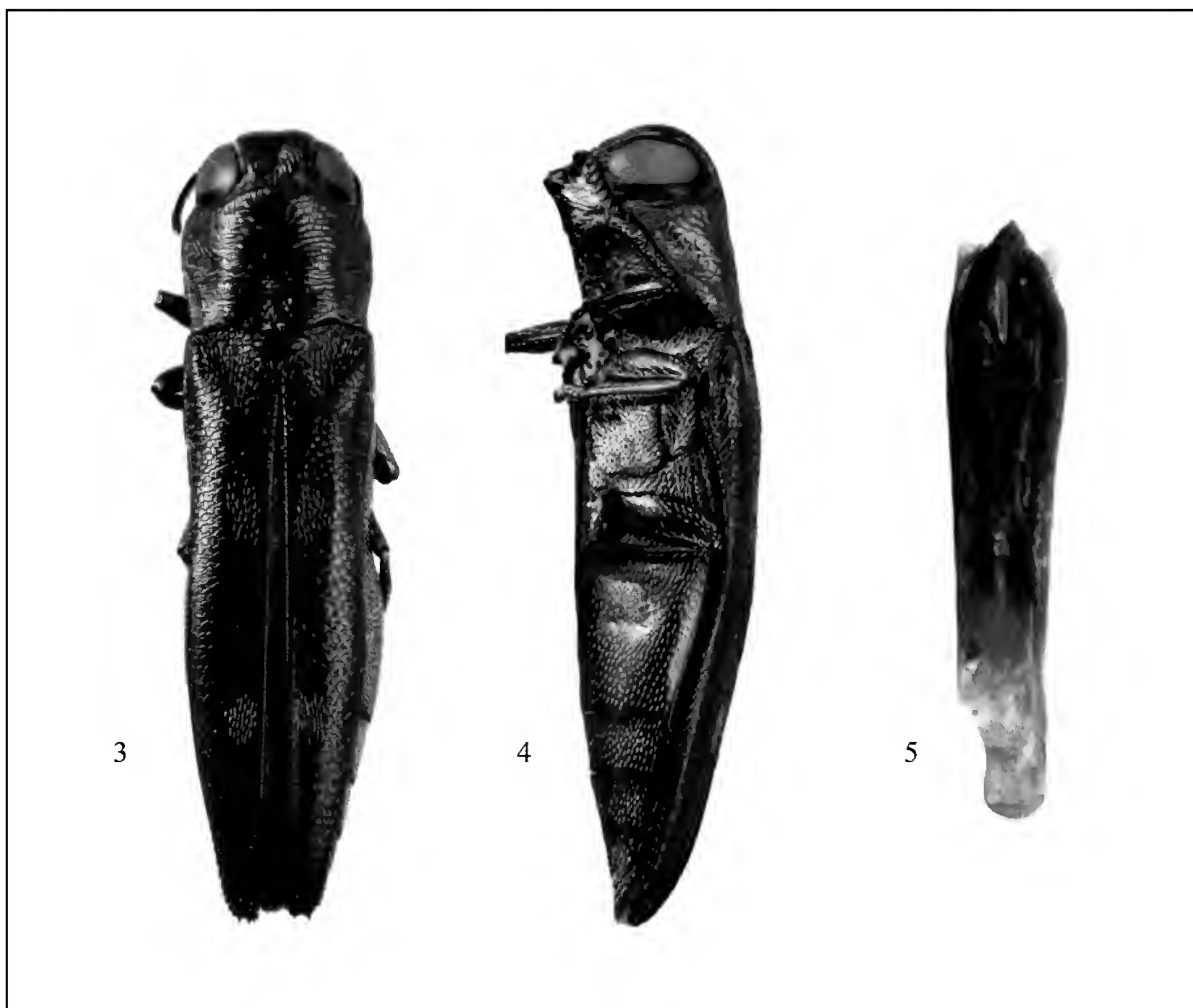### *Agrilus* (*Agrilus*) *flechtmanni* n. sp.

EXAMINED MATERIAL (Figs. 3–5). Holotypus male: BR[azil], SP, Ilha Solteira, UNESP campus, 20°25'11.65"S - 51°20'28.19"W, ex broken *Anadenanthera falcata* [now *macrocarpa,* Fabaceae family], 3.III.2011, Flechtmann C.A.H. legit (MEFEIS). Paratypes: 1 male and 3 females, idem, respectively 18.III.2011, 26.II.2011, 19.III.2011, 10.IV.2011; 3 males and 5 females, Brazil, SP, Três Lagoas reforested degraded area, 20°44'55"S - 51°39'36"W, V, Nascimento leg., ex Cerambycidae-girdled *Anadenanthera macrocarpa* branch on the ground, 15.VII.2013 (MEFEIS and MCCI)

DESCRIPTION OF HOLOTYPUS. Length 4.4 mm. Lengthened form; uniformly bronze-brown, less brilliant, with yellow pale pubescence on elytra forming three couples of pubescent spots. Vertex slightly depressed, ¼ width of anterior margin of pronotum. Frons flat, green, glabrous, brilliant, with sericeous sculpture. Clypeus without trans-versal carina. Antennae short, green, serrate from antennomere 4. Pronotum with lateral margins anteriorly arcuate and posterior angles less acute. Premarginal carinula entire. Marginal carinae subparallel, separated from base. Disc with a slight depression before the scutellum. Sculpture transverse and thickened. Anterior prosternal lobe cut in the middle. Prosternal plate parallel-sided, bordered. Scutellum carinate. Elytra with apices rounded and denticulate. The first pair of elytral spot is on the humeral callus, the second and third along the suture before the middle and at the apical three-quarters respectively; few thin hairs join the first and second spots. Ventral side darker than the dorsum, uniformly covered by short thin pubescence. Last visible ventrite rounded at the apex. Legs with green reflections. Metatarsus shorter than metatibia, basal metatarsomere shorter than the sum of the following two (1<2+3). All claws bifid. Aedeagus is shown in figure 5.

VARIABILITY. Length from 4.4 to 5.5 mm. In some specimens the first and second couple of elytral pubescence appear clearly separate without the thin pubescence among them that characterize the holotype. The females have frons copper and all claws bifid as the males.

ETIMOLOGY. After the name of the holotype collector.

Figures 3, 4. *Agrilus* (*Agrilus*) *flechtmanni* n. sp., paratype female, lenght 5.5 mm. Figure 5. *A. flechtmanni* n. sp, aedeagus, 1.4 mm.

REMARKS. For the shape, dorsal color and the elytral spots, *A. flechtmanni* n. sp. is similar and may be confused with *A. aegrotus* (Curletti et Migliore, in press).

A. aegrotus differs for having the frons smooth and not sericeous, the prosternal plate bordered and enlarged at the top, sterna minus pubescent and metatarsomeres more lengthened, with tarsal formula 1=2+3+4.

ACKNOWLEDGMENTS

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and in many instances of the plants upon which they are found. London, Printed for the author, volume 2, plates 51–98 with text, not paginated.

Serville A., 1835. Nouvelle classification de la famille des Longicornes. Annales de la Société entomologique de France, 4: 5–100.

A new species of rissoid of the genus *Alvania* Risso, 1826 from the E-Sicily: *Alvania maximilicutiani* n. sp. (Gastropoda Rissoidae)

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ABSTRACT

Alvania maximilicutiani n. sp. is here described and figured as a new Mediterranean species from the E-Sicily. The most similar species in morphological characters are *A. clathrella* (Seguenza L., 1903), *A. dalmatica* Buzzurro et Prkić, 2007, *A. dianiensis* Oliverio, 1988, *A. dictyophora* (Philippi, 1844), *A. hallgassi* Amati et Oliverio, 1985. All these species and other similar Mediterranean and not Mediterranean congeners are here compared to the new species, which differs by the very minute dimensions, being one of the smaller *Alvania* ever described, the protoconch morphology and the colour pattern of the external soft parts. The Macaronesian *A. piersmai* Moolenbeek et Hoenselaar, 1989, *A. poucheti* Dautzenberg, 1889, *A. spreta* (Watson,1873) and other congeners are furthermore compared to *A. maximilicutiani* n.sp. The new species could also resemble a dwarf form of *A. lanciae*, but to a more deepened exam of the shell the latter species appears morphologically very different in both protoconch and teleoconch characters. The type material of *A. maximilicutiani* n.sp. was collected in very shallow waters in the rocky shores of the small village S. Giovanni Li Cuti (Catania, Italy).

KEY WORDS   Gastropoda; Rissoidae; new species; taxonomy; Mediterranean Sea; Recent.

Received 13.04.2014; accepted 19.05.2014; printed 30.06.2014

INTRODUCTION

Rissoids of the genus *Alvania* Risso, 1826 undergone a high adaptive radiation and are uniformly distributed along the main marine biocenosis. Some Authors debated whether they could be considered as representative species of a separated family (Golikov & Starobogatov, 1975), mainly based on anatomical proofs which other Authors, through further deepened studies, considered not as clear and stable characters but only as anatomical schemes variable among species (Ponder, 1984). The anatomy of *Alvania* is thus comparable to that of *Rissoa* Desmarest, 1814 being the animals rather similar in structure and differences are due mainly to different habitat preferences (Ponder, 1985). Similitudes are close related as concerns the animal and shell between genera *Alvania* and *Crisilla* Monterosato, 1917 being the latter tentatively separated only as a subgenus by Ponder (1985), but currently considered as a valid separated genus for the actual checklists (Clemam, 2013; MarBEF, 2013).

The Mediterranean represents an elective geographic area where rissoids exhibit wonderful patterns of speciation (Bouchet in Giannuzzi-Savelli et al., 1996), due to its environmental variability of habitats. With 160 species of rissoids the Mediterranean represents the most diverse site in the world and plays an important role as one of the source of rissoid-flow in the world (Ávila et al., 2012). In the

Mediterranean sea and the adjacent Macaronesian area (E-Atlantic) the genus *Alvania* is the most abundant of rissoid species (Gofas, 1990; Van der Linden, 1993; Hoenselaar, H.J. & Goud, J., 1998; Ávila, 2000; 2012), while lower number of species are also present in the western Atlantic and Indo-Pacific Ocean (Bouchet in Giannuzzi-Savelli et al., 1997; Garilli & Parrinello, 2010), E-Africa (Gofas, 1999). In particular, species with non-planktotrophic development seem to be limited to only the western or the eastern part of the Mediterranean (Garilli & Parrinello, 2010). Moreover, this basin is the site with higher number of endemic species of *Alvania* (Ávila et al., 2012). Many species of Rissoidae are reported as endemisms to restricted areas of Mediterranean, particularly islands (Bogi et al., 1983; Oliverio, 1986; Amati & Oliverio, 1987; Oliverio, 1988; Giusti & Nofroni, 1989; Oliverio & Amati, 1990; Cecalupo & Quadri, 1995; Margelli, 2001; Buzzurro, 2003; Micali et al., 2005; Buzzurro & Landini, 2006; Buzzurro & Prkić, 2007; Oliver & Templado, 2009). Numerous species of molluscs, among which some of *Alvania*, are described as endemic to the E-Sicily, which represents a high hotspot for the speciation of molluscs in the Mediterranean, due probably to its variety of different environments present in this area: *A. dictyophora* (Philippi, 1844) and *A. clathrella* (Seguenza L., 1903, ex Monterosato ms) are an example.
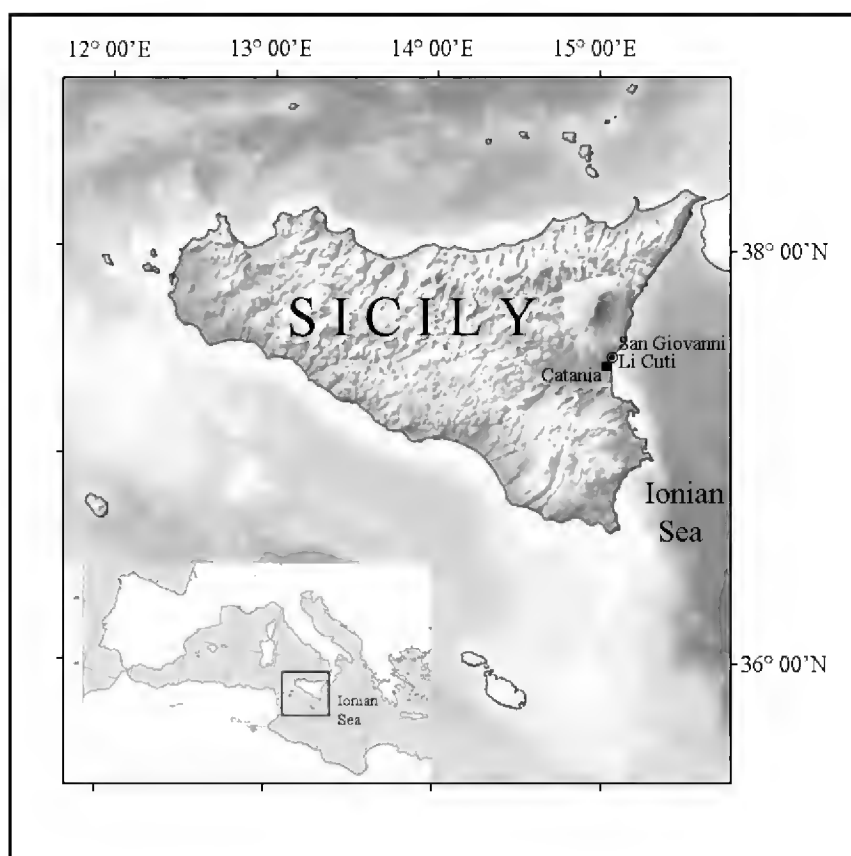
A new species of *Alvania*, named *A. maximilicutiani* n.sp., was found in the E-Sicily coasts (Fig. 1) and is here described and figured as new for science and compared to the close similar congeners.

MATERIAL AND METHODS

Living materials of the new species were collected by brushing the surface of little lava stones inside a net of 0.5 mm mesh at a depth of 0.5 to 2.5 m. No empty material was found among the shell grit collected handily with ARA. Drawings of the external soft parts were obtained observing the living animals in aquarium. Fossil materials of similar species were studied and compared to the new *Alvania*.

ACRONYMS. Museo del Dipartimento di Biologia Animale, University of Catania, Italy (MBAC); Alberto Villari malacological collection, Messina, Italy (AVC); Bruno Amati malacological collection, Roma, Italy (BAC); Danilo Scuderi malacological collection, Catania, Italy (DSC).

Alvania maximilicutiani n. sp.

Examined material. Holotypus, Catania, E-Sicily, Italy: S. Giovanni Li Cuti, in shallow water, under lava stones. Paratypi, same data of holotypus, 11 living specimens.

Holotype in MBAC, n. MBLMC-CT-79; 1 paratype in AVC; 1 paratype in BAC. Other paratypes in DSC.

Description of holotypus. Shell (Fig. 6) ovate-conic, stout, relatively strong, imperforate, 1.1 mm high x 0.65 mm broad. Teleoconch constituted by 1.9 whorls in adult specimens, separated by marked sutures, bearing two spiral chords on the first and rather on the majority of the last whorl: only a trace of a third spiral chord appear almost at the end-half of the last whorl. Spiral micro sculpture is present over the surface of all the tele-whorls. The axial ribs are angular, marked, opisthocline and in number of 12 on the first tele-whorl, 14 on the body whorls, never reaching the base of the shell. The first adapical spiral chords are less marked than the axial ribs and become stronger at the base. They form a cancellate sculpture at the intersection with the axial ribs, with not marked, almost rounded,

Figure 1. Study area.

tubercles at the crossing points. At the base four well marked spirals are present, except the last which appears almost vanishing. Very thin spiral threads cover the interspace and run over the axial ribs too. The last whorl forms rather 76% of the total shell height. Aperture ovate, drop shaped, with thick uninterrupted peristome, which bears no denticles and form a varix in the outer lip. Background colour almost dark-brown in protoconch and first tele-whorl, creamy in the body-whorl with two small darker bands, the first sub-sutural, which forms dark spots in correspondence of the tubercles (one every three axial ribs) and the second, larger, at the base.

Protoconch (Figs. 10, 11) low-rise, paucispiral with direct development, constituted by 1.3 to 1.5 regularly convex whorls. Protoconch I slightly less than 1 whorl, with 7-8 very thin spiral threads. Protoconch II with 13-14 equally thin spiral threads.

The living animal (Fig. 12) is whitish as background colour and bears dark-brown to almost black strips on head, anterior foot and opercular area. In the head they are "V" shaped just before the eyes and straight in the snout and foot, surrounding the operculum and extending to the edge in the middle of the foot: it is not visible on the sole of the foot, where a whitish gland is visible in transparency in the middle. The same gland is visible under the operculum. Two whitish granular masses are also visible on the snout just near the eyes. Few white stains are present on both the cephalic tentacles. Only one metapodial tentacle is visible. Operculum (Fig. 9) thin, paucispiral, with eccentric nucleus.

VARIABILITY. All the fully developed adult specimens collected seems not to differ in size (1–1.2 mm high x 0.65 mm wide) (Figs. 2–5; 6–8). The only character which seem to vary is the colour of the body whorl, entirely dark brown to creamy with brown spots. Protoconch and first tele-whorl are always darker. The colour variability could be linked to the shady habits of the animal. If so, the paler coloration could be considered typical and the darker an adaptation.

ETYMOLOGY. The specific name is in memory of my father, Massimo, and also recalls the small village, locus typicus of the present species, where he spent his life as a fisherman and where he conducted me to begin my marine biology career and my malacological studies.

BIOLOGY AND DISTRIBUTION. The new species seem confined exclusively to rocky very shallow waters, under stones. Only living specimens were hardly collected. It was never recorded among shell grit. The new species was collected only from the type locality in the Jonian sea, but, because of its very small dimensions, it could be unnoticed and its real distribution range could be wider.

COMPARATIVE NOTES. Because of the very small dimensions of adult specimens, the peculiar characters of the teleoconch, particularly the number of whorls, the sculpture and the colour pattern of the shell, the protoconch sculpture and the external soft parts of the living animal, the new species is unique among all the Mediterranean and not Mediterranean species of the same genus. The comparative notes here following explore the possibility that a dwarf form of a still known species is involved and demonstrate the validity of the new species. So, among Mediterranean species, *A. maximilicutiani* n. sp. is morphologically similar to *A. lanciae* (Calcara, 1845), *A. aeoliae* Palazzi, 1988, *A. datchaensis* Amati et Oliverio, 1987, *A. fractospira* (Oberling, 1970) on one hand and to *A. dictyophora*, *A. hallgassi* Amati et Oliverio, 1985, *A. dianiensis* Oliverio, 1988, *A. dalmatica* Buzzurro et Prkic, 2007 on another hand. In the meantime the new species is here compared to some Macaronesian congeners: *A. grancanariensis* Segers,1999, *A. hoeksemai* Hoenselaar et Goud, 1998, *A. moniziana* (Watson, 1873), *A. piersmai* Moolenbeek et Hoenselaar, 1989, *A. poucheti* Dautzenberg, 1889, *A. spreta* (Watson,1873).

The possibility that the new species could be a dwarf form of *A. lanciae* (Fig. 13), or of a close similar species as *A. datchaensis*, *A. fractospira*, was the first eventuality explored. but the different protoconch, lacking the "orange skin" sculpture, colour pattern of shell and soft parts make it easily recognisable. Amati (2012) recently re-described and figured *A. lanciae*, *A. arguta* Locard et Caziot, 1900 and *A. consociella* Monterosato, 1884, considering these two latter taxa, often distinguished for the stouter shape and the larger dimensions, as synonyms of the former. In the same paper he presented an exhaustive comparison of *A. lanciae* with *A. datchaensis* and *A. fractospira*.

A. aeoliae has a more slender teleoconch, with a colour pattern also similar, being almost darker in the first whorls, paler with two darker spiral bands

in the body-whorl, but they do not form any stain on the axial ribs. The protoconch has a different shape, more elevated and with dense undulated spiral sculpture like that of *A. lineata*, and the axial ribs of teleoconch, which are opisthocline too, are more numerous and with heavier spiral sculpture.

Two new species of *Alvania* were lately described for the Mediterranean (Tisselli & Giunchi, 2013): *A. bozcaadensis* Tisselli et Giunchi, 2013 and *A. campanii* Tisselli et Giunchi, 2013. They are both quite different from *A. maximilicutiani* n. sp. on account of shell and protoconch differences. The former is a species close similar to *A. dorbignyi* (Audouin, 1826) as for the almost smooth protoconch and the teleoconch, with characters of *A. lineata* mixed with those of *A. discors* (Allan, 1818). The latter seems linked to the *A. datchaensis/A. fractospira* group of species as for both teleoconch characters and protoconch, with "orange skin" sculpture.

Typical *A. dictyophora* (Fig. 14) are usually 2.5–2.8 mm, bear three spiral chords (excluding the 4 basal, present in the space between the upper attachment of the external lip and the end of the base of the shell) and 9-10 axial ribs in the bodywhorl. But small specimens of this species (up to 1.4-1.7 mm) with only 2 spiral cHords are known (Fig. 15; Palazzi & Villari, 2001, Fig. 27). These dwarf forms of *A. dictyophora* resemble in shell morphology the new species, which however is easily distinguishable by the smaller dimensions, the lower number of whorls, the different protoconch and colour pattern of the shell, the less marked spiral cords which cross the more opisthocline axial ribs.

Shells of *A. hallgassi* and *A. dianiensis* are almost close similar, being the former only more delicate in teleoconch sculpture. The protoconch in both species is constituted by 6 marked spiral chords, on a smooth (*A. hallgassi*) or granulated with small dots background (*A. dianiensis*). The new species has the teleoconch different in dimensions, shape, shell sculpture and colour pattern and the protoconch with a different form and more conspicuous and delicate sculpture.

A. dalmatica is a species described few years ago and shares with the above mentioned species a bodywhorl with a similar sculpture, only slightly more marked and with pointed tubercles at the intersections. The new species differs for having a different shell colour pattern and sculpture of the last whorl, while the similar protoconch differs for the less dense and more marked spiral threads.

A. clarae (Nofroni et Pizzini, 1991) is an easter Jonian species described for Zakinthos, Greece in recent time, which shares with the new species a similar protoconch sculpture and shell colour pattern. Compared to the new species, it is higher and with one more tele-whorl. The shape of teleoconch is much more slender, with a different sculpture, dense of marked tubercles some of which (those on adapical first spiral chord) are oriented upward. The subsutural zone is wider. The less wide base bears one spiral chord less. The protoconch is shorter, less wide, almost white and bears more marked spiral sculpture.

A problematic taxon is *A. peloritana* (Aradas et Benoit,1870): Scuderi & Terlizzi (2012) exposed their idea of this species, based on topotypical materials, which is different in both protoconch and shell characters from the new species.

In a recent paper Garilli (2008) restored *A. cingulata* (Philippi, 1836), which have a protoconch similar to that of the new species as for general outline and sculpture, but the spiral threads are lower in number and the teleoconch is very different in general outline, more similar to a big *A. tenera*, and sculpture, composed by thin and numerous axial ribs crossed by spiral lines of the same consistence.

Among the numerous Macaronesian congeners *A. maximilicutiani* n. sp. is here compared with those of small dimensions and close similar morphological characters. The new species resulted peculiar in sculpture of teleoconch, characters and dimensions of protoconch, resulting the smallest species of *Alvania* in this area too, sculpture of teleoconch and characteristics of protoconch. The morphology of the external soft parts of many species of this geographical zone are unknown: for this reason comparisons between species of the living animals were not possible.

A. grancanariensis is a species which could be referred to the Mediterranean *A. lanciae* group, as for general outline and sculpture of the teleoconch. The darker colouration of the protoconch and first tele-whorls make it similar to the new species, which however could be easily distinguished for the protoconch characteristics. Another congener whose coloration is similar to this latter species is *A. hoeksemai*, but the predominant spiral sculpture, the heavier shell aspect and the different protoconch make it easily differentiable from the new species.
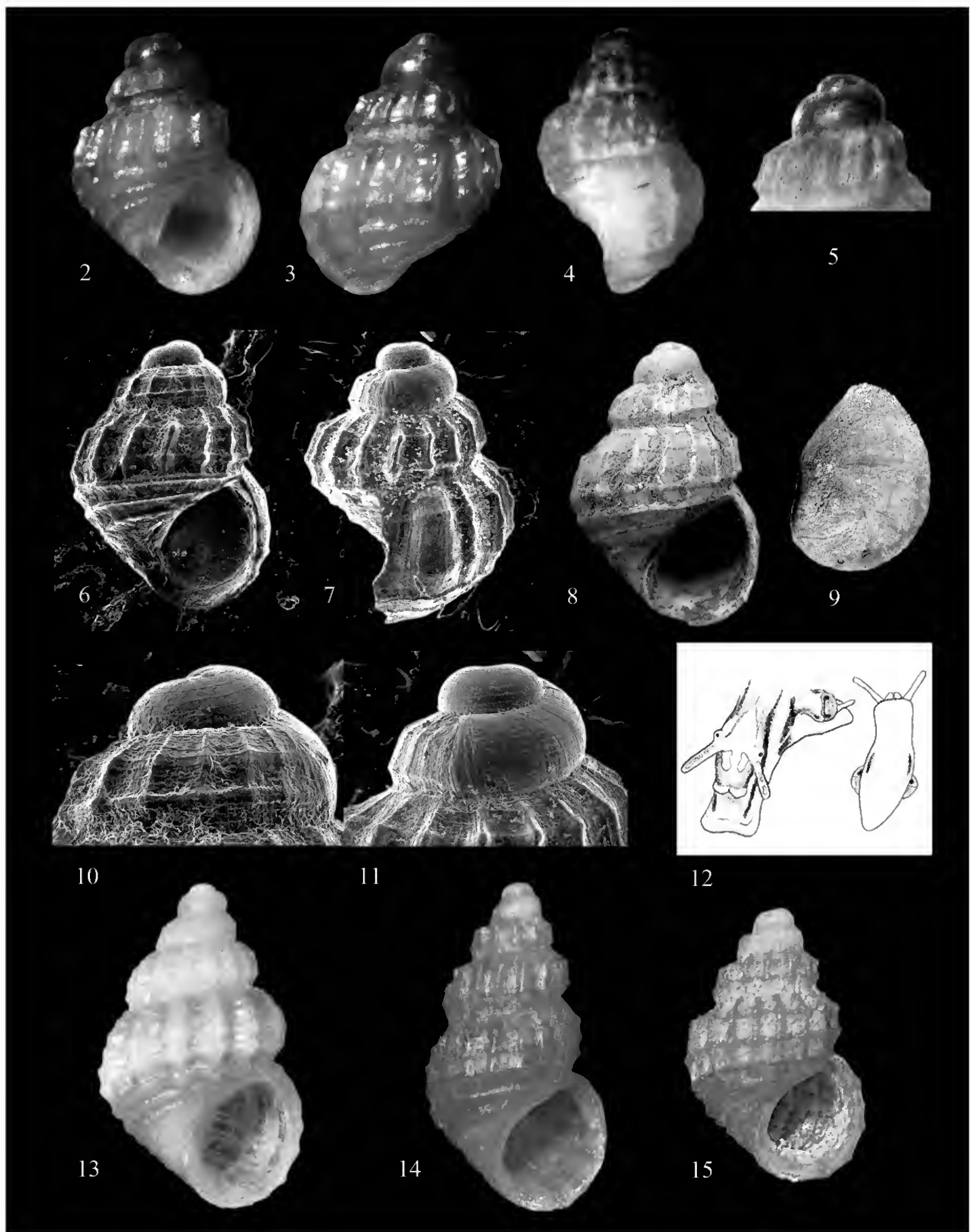
Figures 2–12. *A. maximilicutiani* n. sp. Figs. 2–5: paratype, S. Giovanni Li Cuti, H: 1 mm (D. Scuderi coll.). Fig. 5: detail of protoconch, same data. Fig. 6: holotype, SEM photograph, H: 1.0 mm (MBAC). Figs. 7, 8: paratypes, same data of holotype, SEM photograph, both H: 1.1 mm (B. Amati coll. and A. Villari coll.). Fig. 9: upward view of operculum, H: 600 μm (same data of Fig. 7). Fig. 10: protoconch of holotype (257x328 μm), front view. Fig. 11: protoconch of paratype (267x300 μm), lateral view. Fig. 12: external morphology of the soft parts. Figure 13. *A. lanciae*, S. Giovanni Li Cuti, H: 2.6 mm. Figures 14, 15. *A. dictyophora*, Salina, Eolie Is., H: 2.7 mm and 2.0 mm (B. Amati coll.).

The Madeiran *A. moniziana* shares with the new species the general shape and number of tele-whorls, but it is bigger, lacks axial sculpture and is almost entirely whitish in colour, while the proto-conch is different at all.

Apart the size, almost double, the different pattern of shell colour, more light coloured with marked white stains in the peripheral line of each whorl, the sculpture, constituted by stronger axial ribs and more numerous spiral chords, expecially in the peripheral zone, and the different protoconch distinguish *A. piersmai*, a small Canary recently described species, from the new species.

A. poucheti is a small (2 mm high) species, dark in colour, which resembles the new species for general shape, but differs in dimensions, shell and protoconch sculpture.

Juveniles specimens of *A. spreta*, a small dark shell Madeiran species, resemble *A. maximilicutiani* n. sp. as for the opisthocline shell sculpture and the coloration. But the former is higher, the number of whorls being equal, with more incised sutures and more numerous spiral chords, which give to whorls a less stouter aspect; the protoconch is different in colour and sculpture and the external lip in adult specimens is thicker and more rounded.

According to literature data (Dall, 1889, 1927; De Jong & Coomans, 1988; Leal, 1989), among Western Atlantic congeners few species properly belonging to *Alvania* recall the new species in dimensions and general shell features. *A. auberiana* (d'Orbigny, 1842) has a similar colour pattern, but is bigger, bears three spirals of the same thickness of the axial ribs above the outer lip, of which the uppermost is separated from suture, and has a different protoconch. As the latter species, *A. faberi* de Jong et Coomans, 1988 bears a third spiral chord on the last tele-whorl, while the uppermost colour band is continuous and the protoconch has different morphology. The general shape, dimensions and shell sculpture, together with the different proto-conch, discriminate *A. nigrescens* Bartsch et Rehder, 1939 from the new species. Another small similar Caribbean congener is *A. moolenbeeki* De Jong et Coomans, 1988 which shares with the new species similar dimensions reaching 0.9 mm in adult specimens, but it is almost entirely white and has spiral sculpture predominant on the two tele-whorls, a clear umbilicus is present and the proto-conch has different dimensions and sculpture.

Two eastern Pacific congeners resemble the new species in morphology, according to literature data (Bartsch, 1912; Backer et al., 1930; Bartsch & Rehder, 1939): both *A. purpurea* Dall, 1871 and *A. cosmia* Bartsch, 1911 are similar in teleoconch sculpture, constituted by only two spirals above the outer lip. Therefore, compared to the new species, they are almost double in dimensions, they are constituted by three rather higher tele-whorls in adult specimens and show a different shell colour pattern; the protoconch is different. Three more species of the same geographical area, *A. almo* Bartsch, 1911, *A. tumida* Carpenter, 1857 and *A. oldroydae* Bartsch, 1911, share with the new species a similar general outline, almost stubby and swollen, constituted by only two or three tele-whorls. They all have a different sculpture, mainly constituted by spiral keels and numerous less marked axial ribs, a different shell colour pattern and protoconch.

Concerning the external morphology of the soft parts the new species shows a peculiar character as concerns the presence of only one single metapodial tentacle. Usually species of *Alvania* are reported to bear 3-7 metapodial tentacles (Ponder, 1985) and previous observations of one single metapodial tentacle by Jeffreys (1867) for *A. punctura* (Montagu, 1803), *A. lactea* (Michaud, 1832) and *A. abyssicola* (Forbes, 1850) have been rejected on the basis of Clark's (1852) observations (Ponder, 1985). Now the question on the number of metapodial tentacles in species of this genus could be re-opened on the basis of the present observations.

Among fossil species *A. maximilicutiani* n. sp. shows some grossly resemblance with A. *circum-cincta* Seguenza G., 1873 and *A. bicingulata* Seguenza L., 1903 and with species of *Galeodinopsis* Sacco, 1895 (Garilli, 2008), but show substantial differences in dimensions, teleoconch sculpture and protoconch shape and sculpture.

ACKNOWLEDGMENTS

Macaronesian species to compare. Andrea Di Giulio (Dipartimento di Biologia, Università Roma Tre, Roma, Italy) and Mauro Cavallaro (Istituto di Veterinaria, Messina, Italy) allowed the realisation of the SEM photographs.

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Odostomia crassa Jeffreys, 1884 junior synonym of Tibersyrnola unifasciata (Forbes, 1844), new combination (Gastropoda Pyramidellidae)

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ABSTRACT   Following the comparison with photos of type material of *Odostomia crassa* Jeffreys, 1884, (Gastropoda Pyramidellidae) deposited at the British Museum of Natural History, and further observations on specimens from whole Mediterranean, *O. crassa* is proved to be junior synonym of *Eulimella unifasciata* (Forbes, 1844). The latter is here placed in genus *Tibersyrnola* Laws, 1937 on the basis of the constant presence of flutings inside the whorls.

KEY WORDS   Pyramidellidae; *Tibersyrnola*; new combinaton; recent; Mediterranean Sea.

INTRODUCTION

The species *Odostomia crassa* Jeffreys, 1884 (Gastropoda Pyramidellidae) was described on partially broken specimens and fragments collected in north-eastern Atlantic and Mediterranean (Adventure Bank, Sicily channel, 30-92 fms [corresponding to 50-150 m]). In the original description the new species was compared only with *Eulimella scillae* (Scacchi, 1835) and not with *E. unifasciata*, that is also reported and drawn in the same work. We suppose that this is due to the lack of complete specimens, and the impossibility to see the shell profile, as well as the lack of brown spiral band over the whorls, possibly due to the bad preservation of studied fragments.

ORIGINAL DESCRIPTION (Jeffreys, 1884: 350): "*Shell cylindrical, remarkably thick and strong, opaque, and glossy: sculpture none, except microscopic lines of growth and the grooves with the outer lip hereafter mentioned, as well as the pe- riphery being slightly angulated: colour ivory-white: spire long and finely tapering: whorls 5 only in the fragments now described, although there would be from 8 to 10 in perfect specimens; they gradually increase in size and are flattened: suture slight, rounded below: outer lip incrassated, furnished inside with 8 to 10 spiral striae or flutings, like those in* O. conoidea, O. tenuis, *and* O. conspicua, *as also in* O. costaria *and other Crag species: inner lip forming an unusually thick and broad glaze on the pillar: umbilicus none: tooth large, solid, prominent, and winding round the pillar. Largest fragment L. 0.25* [about 6 mm], *B 0.085* [about 2.1 mm]."

The species was figured by Jeffreys (1884: tav. XXVI, figg. 7, 7a), but the original drawings, here reported (Figs. 1, 2), are not clear and have not allowed a sure recognition of this species by the later Authors. Jeffreys compared the new species only with *E. scillae* (Scacchi, 1835), stating that main characters for separation are the "*strong tooth and inside fluting of the outer lip*". The fluting of the outer lip seems to be the only character that separate it from the other Lusitanic species.

Nordsieck (1972) found that the Jeffreys's name was pre-occupied by *Odostomia crassa* Thompson, 1845 and proposed the new name *Syrnola* (*Tibersyrnola*) *wenzi* Nordsieck, 1972.

Van Aartsen (1984), after examination of the type material, concludes that this species is known only for the original description and some fragments at the British Museum of Natural History, no one complete of protoconch.

This species was included in the recent lists of species (Piani, 1980; Bruschi et al., 1985; Sabelli et al., 1990; WORMS (World Register of Marine Species, http://www.marinespecies.org/aphia.php?p= taxdetaild&id=141048 searched on 21/03/2014) with full validity, while in CLEMAM (Check List of European Marine Mollusca Database, http://somali.asso.fr/clemam/index.clemam.html searched on 11/01/2014) it is considered doubtful.

MATERIAL AND METHODS

Thanks to the courtesy of Dr. Kathy Way and Ms. Andreia Salvador (BMNHL) we obtained the photos of the two broken specimens of the type series deposited at the BMNHL (Figs. 3, 4) with the number 1885.11.5.1998. These fragments correspond exactly with the original Jeffreys's drawings (1884, tav. XXVI, figg. 7, 7a). The larger one (Fig. 3) shows the sign of some fractures on the last whorl, that may have caused the unusal periphery/base profile. The two fragments are in very poor conditions and it is quite surprising that Jeffreys decided to describe a new species based on a so poor material!

In addition we studied about 80 shells of *Eulimella unifasciata* (Forbes, 1844) collected in various localities, covering the whole Mediterranean, at depth ranging from 120 and 500 m (coll. CSR, INR and PMF).

ABBREVIATIONS. British Museum of Natural History, London = BMNHL; Carlo Smriglio collection (Rome, Italy) = CSR; Italo Nofroni collection (Rome, Italy) = INR; Pasquale Micali collection (Fano, Italy) = PMF.

RESULTS

Based on the original description/drawings and the photos of type material, the main character, which is also the unique one, useful for the specific separation is the "*outer lip incrassated, furnished inside with 8 to 10 spiral striae or flutings*". This character has been re-evaluated in the more similar mediterranean *Eulimella* species.

We were really surprised to find out that all the examined specimens of *E. unifasciata*, as intended by all European Authors, show the flutings inside the outer lip, but these are well visible only in fresh and transparent specimens (Figs. 8, 9), that are rarely found; the flutings are observable both in fresh specimens and in old ones but only in fresh and intact specimens it is possible to observe the flutings in transparency. In addition the external lip edge is thin, sharp and smooth, and does not show any sign of internal flutings (Figs. 5, 6), because these are present up to a quarter of whorl from the aperture and became visible only in specimens missing the final portion of last whorl (Fig. 7). In transparent specimens it is possible to observe that the flutings appear just after the embryonic whorls, in number of 3-4 and increase up to 6-8 on the last whorl.

Jeffreys (op. cit.) just after the description of *O. crassa*, lists *O. unifasciata*, pointing out that a specimen from the Gulf of Naples "*shows also a grooved or crenated mouth*".

Di Geronimo & Panetta (1973: 77) reported *Eulimella unifasciata* (Forbes, 1844) for the Gulf of Taranto, pointing out that "*la superficie del labbro esterno, che è rotto presenta dei solchi piuttosto marcati* [the surface of the external lip, that is broken, shows marked grooves]", but also *Eulimella crassa* is reported in the same work as valid species, although the figured specimen is of doubtful determination. Based on above observations we consider that *Odostomia crassa* Jeffreys, 1884 should be considered a junior synonym of *Eulima unifasciata* Forbes, 1844.

As concern the genus where to include this species in, almost all Authors placed it in genus *Syrnola* A. Adams, 1860 with *Syrnola gracillima* A. Adams, 1860 as type species by monotypy. This genus was described as follows (A. Adams, 1860: 405) "*Testa subulata, recta, vitrea, polita; anfractibus planis; suturis impressis. Apertura oblonga; labio in medio plica obliqua instructo; labro simplici, acuto*". Van Aartsen (1994: 85), when dealing with the use of this genus, states: "*It is my strong belief, however, that a fold on the columella is not enough to place species in* Syrnola"; Author also states that there is a possible type material of *S. gracillima*, at the Museum of Victoria, consisting of the lower whorls only, which
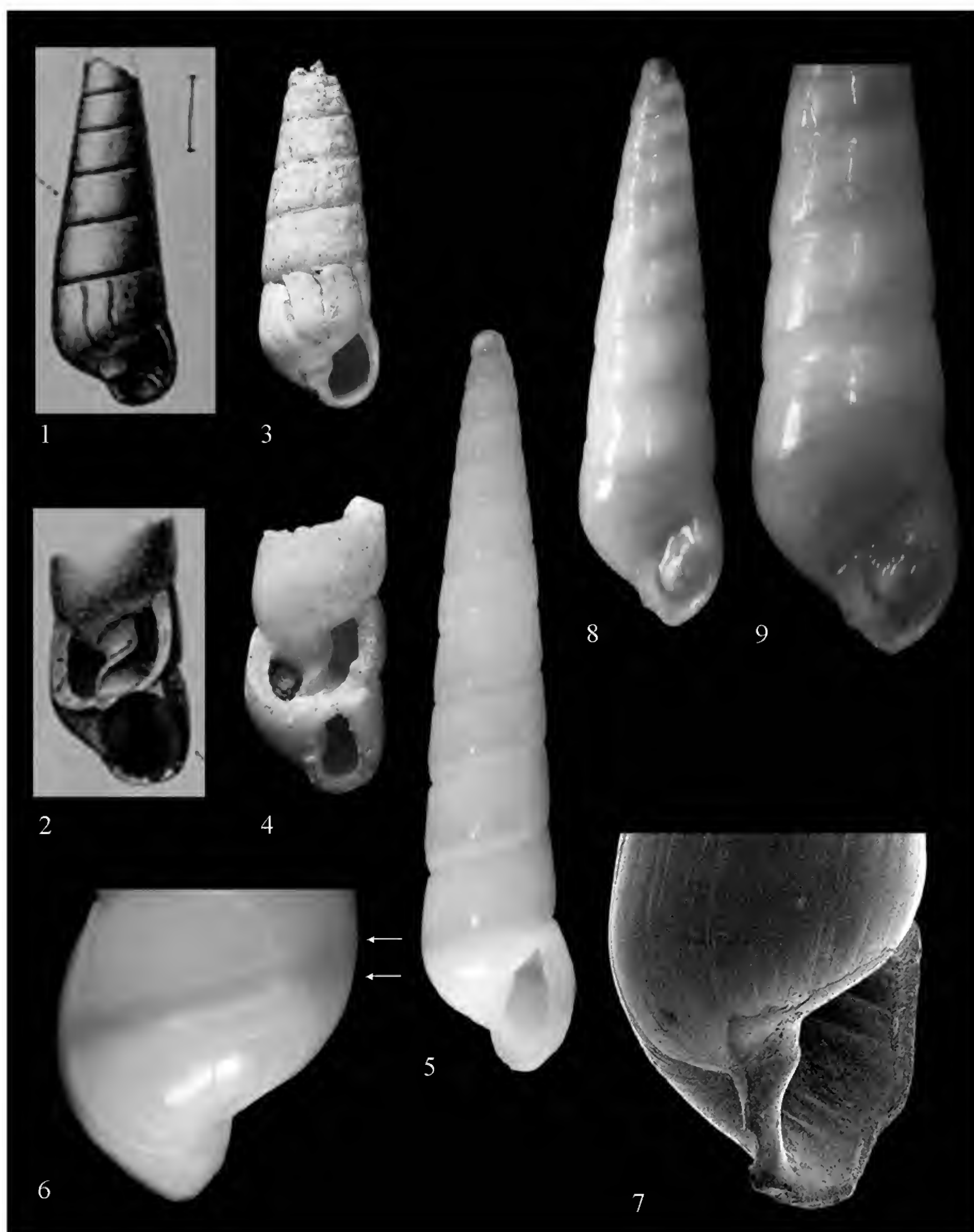
Figures 1–9. *Tibersyrnola unifasciata* (Forbes, 1844). Figs. 1, 2. Original drawings. Figs. 3, 4. Type specimens used for original drawings. Fig. 5. Gorgona Island, LI, - 400 m (height 8.2 mm), the flutings inside the aperture are not visible in front view. Fig. 6. Same specimen of figure 5, the flutings are visible in transparence from the back of aperture (see arrows). Fig. 7. Central Tyrrhenian sea, -380 m; flutings visible in a specimen having broken outer lip. Fig. 8. Anzio, RM, -400 m (4.4 mm), flutings not visible. Fig. 9. Same specimen of figure 8; flutings visible inside all whorls using greater magnification and proper light angle.

does not correspond with original description due to lack of columellar tooth. Really also *E. unifasciata*, if not broken, has a smooth internal lip, therefore a check of type material of *S. gracillima* could clarify the presence of internal grooves.

Van Aartsen (1994) and van Aartsen et al. (2000) have not evaluated the applicability of genus *Tibersyrnola*, as done by Nordsieck.

The subgenus *Tibersyrnola* used by Nordsieck (1972) was proposed by Laws (1937: 303, 309) (type species *Syrnola semiconcava* Marshall et Murdoch, 1923 fossil from New Zealand) with the following characters definition: *"The shell for which this name has been provided have all the characters of* Syrnola, *but in addition the outer lip is strongly lirate internally"*. This taxon has been recently accepted by Beu & Raine (2009) and later on used with the same meaning by Robba (2013).

For the species dealt with in the present note, we therefore propose the binomen *Tibersyrnola unifasciata* (Forbes, 1844). Based on above conclusions and the opinions of Dautzenberg & Fischer (1896) and Peñas & Micali (1999) the updated synonymy shall be:

Tibersyrnola unifasciata (Forbes, 1844) (*Eulima*)

> = *Odostomia crassa* Jeffreys, 1884 not Thompson, 1845, nec *O. pallida* var. *crassa* O. G. Sars, 1878
> = *Syrnola* (*Tibersyrnola*) *wenzi* Nordsieck, 1972 new name for *Odostomia crassa* Jeffreys, 1884 not Thompson, 1845
> = *Eulimella smithi* Verrill, 1881

In the Mediterranean this is the only species to be placed in genus *Tibersyrnola* while some others distributed along the West Africa coast, as *Eulimella endolamellata* Schander, 1994, *E. angeli* Peñas et Rolan, 1997, *E. vanhareni* van Aartsen, Gittenberger et Goud, 1998, *E. boydae* van Aartsen, Gittenberger et Goud, 2000, *Turbonilla candida* de Folin, 1870 (= *Odostomia lamothei* Dautzenberg, 1912 = *O. etiennei* Dautzenberg, 1912), could also be placed in this genus.

ACKNOWLEDGMENTS

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A new record for the American Bullfrog, *Lithobates catesbeianus* (Shaw, 1802) (Amphibia Anura Ranidae), near Rome (Latium, Italy)

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ABSTRACT   The American Bullfrog, *Lithobates catesbeianus* (Shaw, 1802) (Amphibia Anura Ranidae) is native to North America. In Italy the introduction of this species dates back to the thirties of last century and in few years the bullfrog expanded to the point that, at the end of the eighties the species was known in more than 160 sites. In this paper, a new site of presence in Italy of the *L. catesbeianus* is recorded in some ponds at Monterotondo Scalo, a locality near Rome.

KEY WORDS   American bullfrog; *Lithobates catesbeianus*; invasive alien species; Latium; Rome.

INTRODUCTION

Lithobates catesbeianus (Shaw, 1802) is an amphibian of family Ranidae, native to North America. It is a big frog because is able to exceed 30 cm in length and 1600 g of weight. A very large and obvious tympanic membrane is present in the temporal area.

In Europe its presence is confirmed, as well as for Italy, also for Belgium, France (Bordeaux), Germany (Baden-Wurttemberg), United Kingdom (Surrey), Greece, Holland (Breda) and Spain (Cáceres). In Italy the introduction of *L. catesbeianus* dates back to the thirties of the last century and seems to be related to food purposes. Indeed, it can be seen from the literature that the first where this amphibian was released was Mantova and, subsequently, it would spread in short time in other territories thanks to some peasants who would have used it for edible purposes (Albertini & Lanza, 1987).

In few years the bullfrog expanded to the point that, at the end of the eighties the species was known in more than 160 sites (Scali, 2010).

Currently the presence of bullfrog in Italy is less considerable, but reports remain for Lombardy (Bergamo, Brescia, Cremona and Pavia), Veneto (Verona and Rovigo), Piedmont (Asti and Torino), Emilia-Romagna (Bologna, Modena, Ferrara, Piacenza and Reggio Emilia), Tuscany (Firenze and Pistoia) and Latium (in the province of Rome: Maccarese, Torre in Pietra, Pomezia and Tor San Lorenzo). In the year 2000 it was assumed that the populations of Latium were extinct (Bagnoli, 2000), but a subsequent paper confirmed its presence at Maccarese (Pizzuti Piccoli & Cattaneo, 2008).

MATERIAL AND METHODS

The new site where the American Bullfrog was detected, is located on the Via Salaria in locality

Semblera, Monterotondo Scalo, about twenty kilo-
meters from Rome. It is a wetland of ten acres that
consists of four ponds adjacent to the left bank of
Tevere river (Fig. 1).

Originally these were clay quarries used by a
brick factory. At the end of the eighties these quar-
ries were abandoned, filled with waste materials
and subsequently with water. Initially, one of these
small lakes were used for sport fishing. Later were
no more used and this has allowed the rooting of
luxuriant vegetation (Fig. 2).

The hydrobiotope arisen is of some interest not
only for the existence of another species of amphi-
bian, *Pelophylax* klepton *hispanicus* (Bonaparte,
1839), but also for the significant presence of avi-
fauna that is stationed there.

RESULTS AND CONCLUSIONS

The sightings and detections of the croaking of
L. catesbeianus were carried out in all of the four
lakes. Geographic coordinates are the following:
42°03'52.91"N; 12°35'07.83"E.

It has not been possible to quantify numerically
the presence of this frog (Figs. 3, 4), but it was as-
sumed, through visual and auditory detections, that
the population can be significant. The American
Bullfrog is an alien species considered damaging
for native amphibian populations, both for the large
size it can reach, and for its voracity (Scali, 2010).

L. catesbeianus besides is also a vehicle for the
spread of the dangerous fungus *Batrachochytrium
dendrobatidis* (Hanselmann et al., 2004; Garner et

Figure 1. The study area (by Google earth). Figure 2. The study area. Figure 3. *Lithobates catesbeianus* from Montero-
tondo Scalo (courtesy by Alessandro Crea). Figure 4. *L. catesbeianus* from Monterotondo Scalo (courtesy by Alessandro
D'Alessio).

al., 2006; Dejean et al., 2010; Ficetola & Scali, 2010), which is one of the most important causes of rarefaction of numerous species of amphibians in the world (Blaustein & Kiesecker, 2002; Kats & Ferrer, 2003).

Recent studies (Ficetola et al., 2008) have shown that the Italian populations of bullfrog have originated from a considerably small strain, (less than six females), thus highlighting the large expansion capacity and rooting of this invasive species (Scali, 2010).

Therefore, it is necessary to carry out regular monitoring activities in order to record in time and to avoid eventual invasive processes, especially in the colonization of new sites also due to the strong impact which may exert on ecology and community structure of native amphibians (Andreone & Marocco, 1999; Bologna et al., 2000). The greatest danger is represented for native populations of green frog, either as direct prey of *L. catesbeianus*, or as being subject to infection by the fungus *B. dendrobatidis*.

Previously it was mentioned that the introduction of *L. catesbeianus* in Italy is related exclusively to food purposes. On the contrary, the spread of bullfrog in Latium is attributable exclusively to the passive transport by humans. Individuals imported at Maccarese and Torre in Pietra in 1974, came from Castel d'Ario (Mantova) place of origin of the managers of three lakes used for sport fishing in Latium (Bagnoli, 2000). It is surely know that it was common practice to populate the lakes used for sport fishing with a mixture of juvenile fish coming from the areas around Mantova, where the American bullfrog was certainly present with well established populations, hence, together with the fry there may have been many tadpoles of *L. catesbeianus* (Andreone, 2005; Ferri, 2006).

This made it possible that this alien species colonized new areas. Therefore, it could easily be assumed that the presence of bullfrog in this site should be related to the previous use of some of these ponds for the practice of sport fishing.

ACKNOWLEDGMENTS

Addendum

While the present contribution was in printing, the authors have received a report of the presence of the American Bullfrog, *L. catesbeianus*, in a new site, still in the province of Rome. The new report refers to some quarries currently filled with water, located along the Via Flaminia in Civitella San Paolo. Also these quarries are placed nearby the Tevere river and are about twenty kilometers from the old quarries of Monterotondo Scalo.

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First record of *Pempelia amoenella* (Zeller, 1848) for Western Europe (Lepidoptera Pyralidae)

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ABSTRACT   The first record of *Pempelia amoenella* (Zeller, 1848) (Lepidoptera Pyralidae) for Western Europe is reported. The species was collected in Southern Italy, on the Ionian coast of Calabria, where the vegetation is dominated by *Tamarix*, the known feeding plant of the larvae. Female genitalia are figured for the first time.

KEY WORDS   Mediterranean shrubland; *Tamarix*; diversity; Calabria.

INTRODUCTION

Pempelia amoenella (Zeller, 1848) is a species of Pyralidae belonging to the tribe of Phycitini, subfamily Phycitinae. Described by Zeller (1848) as *Acrobasis amoenella*, was sometimes mentioned as *Salebria amoenella* and now is included in the genus *Pempelia* (Hübner, 1825). Mann (1867) described *Pempelia erberi* for the island of Corfu, Greece, but two years later the same author reported *P. erberi* as a synonym of *P. amoenella*.

This species was rarely reported in literature and very few data on its distribution are published. Zeller (1848) indicated the European Turkey as the locus typicus, without further details. Subsequently in Europe it was collected in Croazia: Southern Dalmatia (Mann, 1869) and Gravosa (Klimesch, 1942), Montenegro: Cattaro (Caradja, 1910), Greece: Corfù Island (Rebel, 1913), Macedonia (Klimesch, 1968), and Russia: Rostov-on-Don Province (Poltavsky et al., 2009) and Astrakhan region,

Astrakhan Nature Reserve (coll. Tatyana A. Trofimova). It was also generically reported for Albania and Romania (Karsholt & Razosky, 1996). Outside of Europe the species was collected inTurkey: Lüle Burgas (Rebel, 1913), Iğdir province (Koçak & Kemal, 2006) and Erzincan (coll. Zoological Museum, University of Copenhagen), Afghanistan (Koçak & Kemal, 2012), Uzbekistan (Koçak & Kemal, 2012),Turkmenistan (coll. Siberian Zoological Museum), Tadzhikistan (coll. Siberian Zoological Museum), Kazakistan: Kyzyl-Orda region, Aral lake, Karatup peninsula (coll. Tatyana A. Trofimova), China: Kashgar, Xinjiang Province (Caradja, 1910) and Mongolia: Hovd Aimak, Mongolian Altai, Uenchin-Gol Valley, 50 km N Uench (coll. Tatyana A. Trofimova).

To date the corotype of *P. amoenella* can be defined as Centrasiatic-South East European.

Larvae feed on *Tamarix* L. (Tamaricaceae). Mann (1867) observed larvae feeding on *Tamarix* sp. where they live in silky structures built around

the vegetative apex. The same behaviour was observed by Klimesch (1942) who also found whitish cocoon of this species on small tree branches.

Larvae pupate at the end of May. Adults were observed to emerge from the end of June to the beginning of July near the coastal line in southern Croazia (Klimesch, 1942), whilst in Turkey were collected later during the third week of July at higher altitude (1200-1300 metres).

The habitat of *P. amoenella* is in coastal areas and in salty and arid soils. It is more frequently recorded at low altitude, especially in dune woodlands of coastal habitats, but, in Turkey, its altitudinal range is extended up to 1300 metres.

MATERIAL AND METHODS

A light source was utilised to collect moths during the night. Light source was a 160W mercury-vapour lamp that reflected onto a white vertical screen. Two operators were assigned to collect the moths on the screen surface and on the ground around the lamp.

The collecting site was located on the bed of the Fiumara Trionto in the municipality of Crosia (Cosenza), Southern Italy, at 90 metres of altitude (lat.: 39°33'09"N; long.: 16°45'31"E) (Fig.1).

The so-called "fiumare" are streams with large beds characterised by a torrential regime and developping primarily along a high altitude gradient, then having a high erosive and transporting power. In summertime the bed is usually dry and surface water appears mainly from late September to late June. The light source was positioned near to a small riparian woodland dominated by *Tamarix africana* Poir. and *Nerium oleander* L., mostly associated to *Spartium junceum* L., *Asparagus acutifolius* L., *Rubus canescens* DC., *Crataegus oxyacantha* L., *Rosa sempervirens* L., *Verbascum sinuatum* L., *Lagurus ovatus* L., *Vicia sativa* L., *Arum italicum* Mill., *Galactites tomentosa* Moench, *Dracunculus vulgaris* Schott, *Artemisia vulgaris* L., and *Trifolium campestre* Schreb. Around the small woodlands and where the soil was stabile from some years, grows a garrigue characterised by *Helichrysum italicum* (Roth) G. Donand, *Ephedra distachya* L., otherwise the soil is bare (Fig. 2).
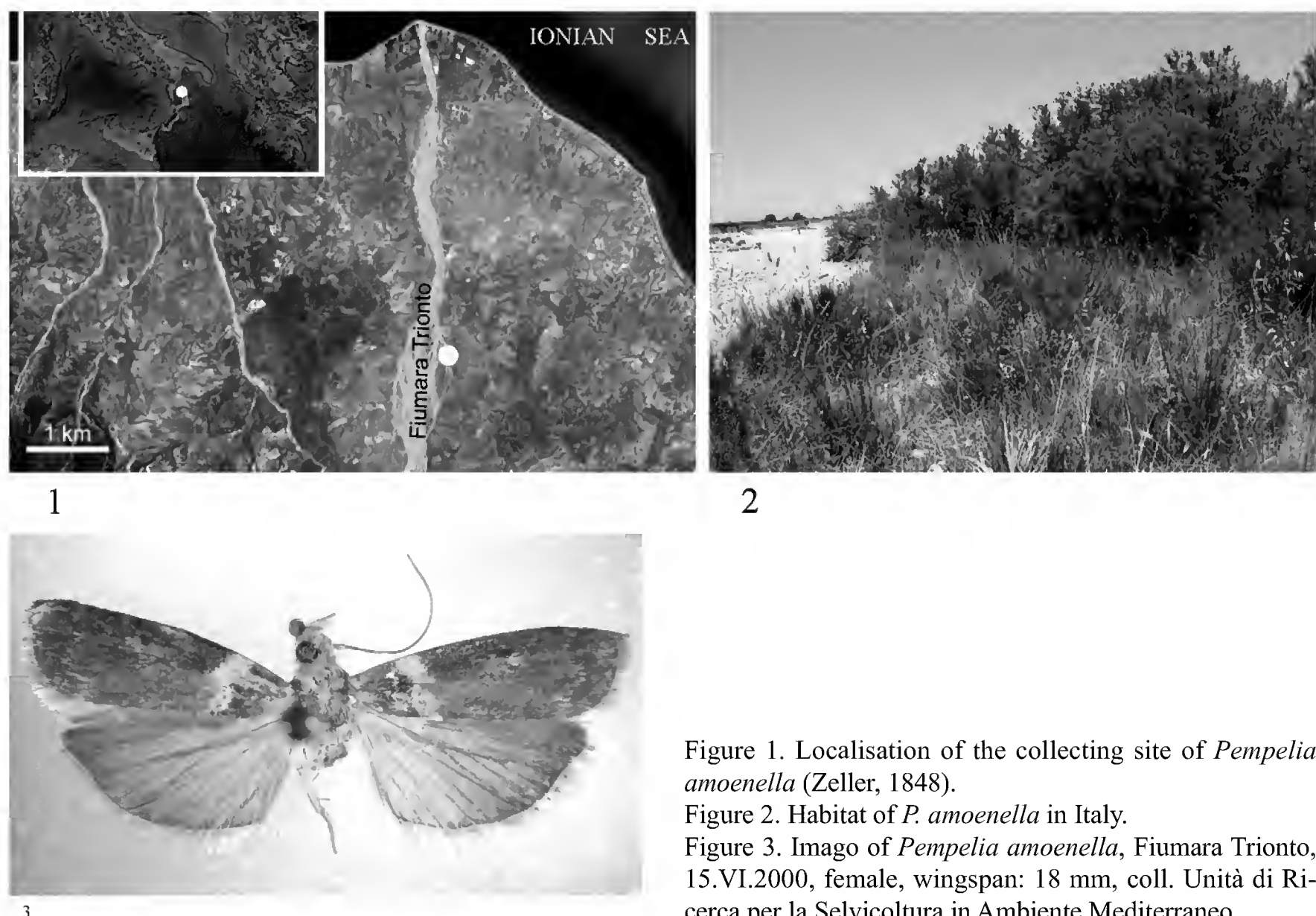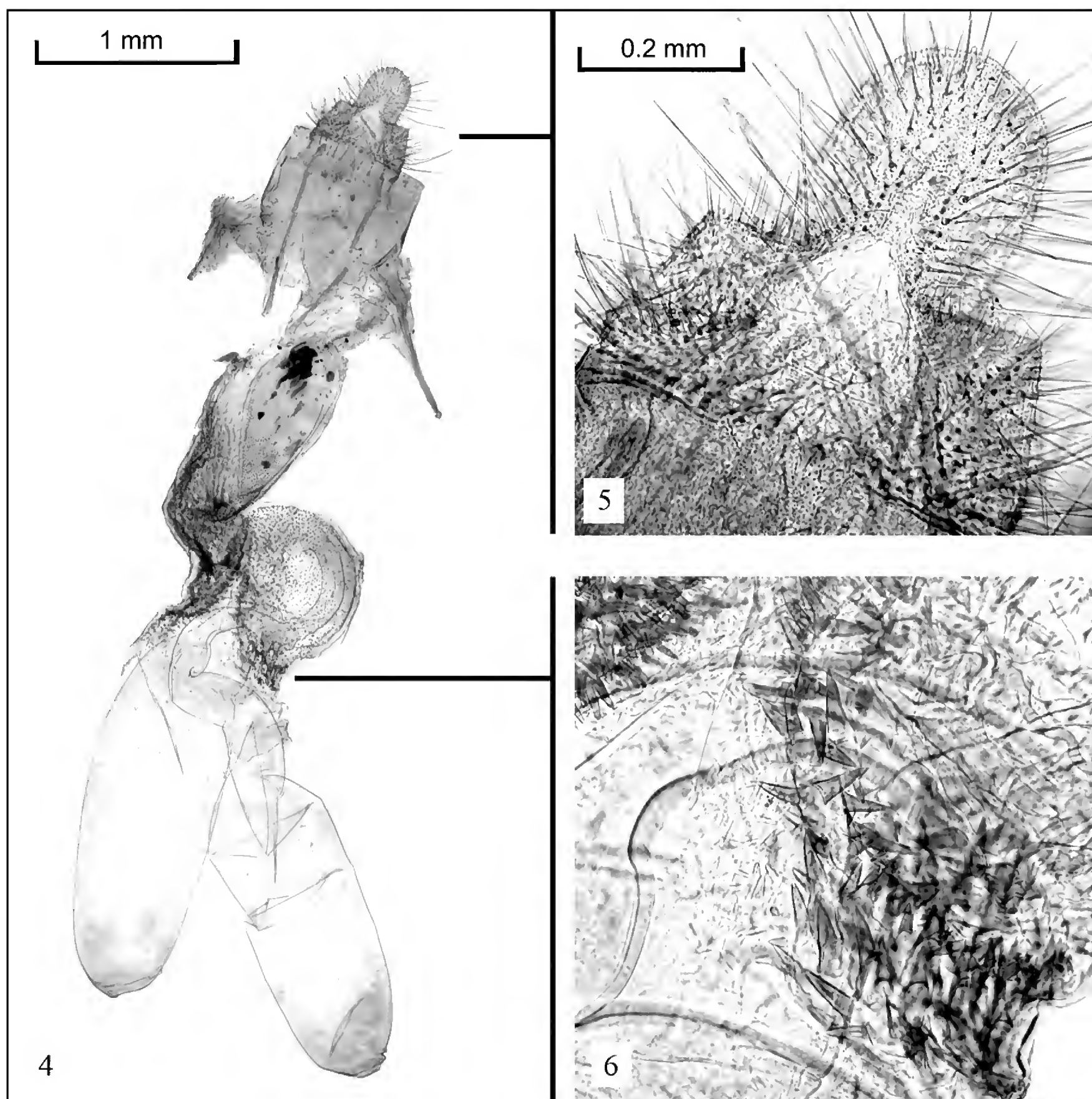

Figure 1. Localisation of the collecting site of *Pempelia amoenella* (Zeller, 1848).
Figure 2. Habitat of *P. amoenella* in Italy.
Figure 3. Imago of *Pempelia amoenella*, Fiumara Trionto, 15.VI.2000, female, wingspan: 18 mm, coll. Unità di Ricerca per la Selvicoltura in Ambiente Mediterraneo.

Figures 4–6. Female genitalia of *P. amoenella*. Fig. 4: general view (gen. praep. CRASAM-012). Fig. 5: details of papillae anales. Fig. 6: details of cornuti on the bursa copulatrix.

RESULTS AND DISCUSSION

One female of *P. amoenella* was collected at light on 15 June 2000 (Fig. 3). This is the first record for Italy and Western Europe of this interesting species. During the night of sampling, mean temperature was of 24°C, humidity rate of 75%, with no wind, the 40% of the moon surface was illuminated and the sky was variably clouded. The sampling session started at 9:10 PM and lasted four hours.

Female genitalia are figured for the first time (Figs. 4–6). The specimen and its genitalia (gen.

praep. CRASAM-012) are conserved in the collection of the Unità di Ricerca per la Selvicoltura in AmbienteMediterraneo (CRA-SAM).

In Italy the habitat of *P. amoenella* is similar to that of localities where the species was previously collected on the eastern coastal areas of Adriatic and Ionian seas, whilst phenology appears to be anticipated due to the higher mean annual temperature in the new discovered range. In fact, our adult female is the earliest known capture for this species.

The presence of trans-ionic species in Southern Italy is not a novelty. In fact, among macrolepidoptera at least 6 species of the Calabrian fauna have a similar range, namely *Oiketicoides lutea* (Staudinger, 1870) (Psychidae), *Anthocaris damone* Boisduval, 1836 (Pieridae), *Idaea determinata* (Staudinger, 1876) (Geometridae), *Aegle agatha* (Staudinger, 1861) (Noctuidae), *Tiliacea cypreago* (Hampson, 1906) (Noctuidae) and *Conistra ragusae* (Failla-Tedaldi, 1890) (Noctuidae).

Further investigation along Ionian coastal areas of Calabria can probably provide more detailed information on the biology of *P. amoenella*.

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An innovative, low-cost, small-scale rearing method for green lacewings (Neuroptera Chrysopidae)

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ABSTRACT
In this paper we describe an innovative, low-cost, small-scale green lacewing (Neuroptera Chrysopidae) rearing method developed in our laboratories over a decade. The main simplifications of our method are represented by the replacement of a yeast-fructose liquid diet for adults with bee pollen loads and by the use of *Tenebrio molitor* Linnaeus, 1758 larvae (Coleoptera Tenebrionidae) as factitious prey for larvae. Moreover almost all the components of the rearing cages derive from common cheap materials which can be easily assembled by anybody. Our method proves to be adaptable from a small laboratory to a local farmer's insectary and its innovative aspects could be adopted in (and/or adapted to) mass rearing systems.

KEY WORDS
bee pollen loads; mealworm beetle; factitious prey; biological control; beneficial insects.

Received 07.06.2014; accepted 18.06.2014; printed 30.06.2014

INTRODUCTION

Green lacewings (Neuroptera Chrysopidae) have long been recognized as effective biological control agents of a wide variety of arthropod pests, but their use has been directed almost exclusively toward the augmentative method for years (Canard et al., 1984; McEwan et al., 2001). So a method of mass-rearing was developed and a few species of the genus *Chrysoperla* Steinmann, 1964 became commercially available during the 1990s in the USA, Europe and China (Wang & Nordlund, 1994; Hunter, 1997). However, despite many promising laboratory tests and several instances of successful field releases, failures often occurred probably due to the lack of integration between research and commercial development (Tauber et al., 2000).

In the last decade, the amount of research on lacewing mass-rearing techniques has been stationary or even in decline and this is linked to the trend of augmentative methods in biological control (Warner & Getz, 2008; van Lenteren, 2012). So reading the recent review of Pappas et al. (2011) on the role of green lacewings in biological control, we did not find any true innovations compared to similar papers written more than 10 years ago (Tauber et al., 2000).

Thirty five years ago, one of us (RAP) began to rear green lacewings on a very small-scale for taxonomic purposes (e. g. in order to obtain all the stages of a given species or the adults from field collected larvae). Working on the staff of Maria Matilde Principi at the Alma Mater Studiorum, University of Bologna, Italy, his starting point was the method described in Pasqualini (1975). This method

was subsequently modified in small steps in order to make it less laborious, less expensive and to save time. Recently, in the laboratory of the ISE-CNR Sassari, Italy, other changes have been made so that it can be used on a laboratory-scale for experimental purposes.

In this paper we want to describe our practices in lacewing rearing because:

i) the well-known large-scale technology is often not suitable when producing lacewings for laboratory purposes and very few papers describe small-scale rearing methods (McEwen et al., 1999);

ii) our method proves to be easily adaptable from a small laboratory to a local farmer's insectary being a simple, low-cost technique;

iii) its innovative aspects could be adopted in (and/or adapted to) mass rearing systems.

ADULT REARING

Over the years we have reared many Euro-Mediterranean species with glyciphagous adults, scilicet pollen-and-nectar-feeders (Pantaleoni, 2014), excluding the genus *Chrysopa* Leach in Brewster, 1815 which is predaceous. We have never had problems obtaining a new generation from gravid wild females, very few species had difficulty in mating and laying eggs. All of the *Chrysoperla* and almost all of the *Pseudomallada* Tsukaguchi, 1995 species that we have dealt with have been reared continuously for several generations, sometimes for years.

For laboratory purposes, specimens were maintained in a climatic chamber with 20 ± 2°C Temperature, 65 ± 5% Relative Humidity, and a 16:8 h Light:Dark Photoperiod. Among the rearing conditions the key factor was the photoperiod, at Mediterranean latitude almost all species enter in diapause under short days.

The adult rearing unit is a cylinder, 100 mm in height and 80 mm in diameter open at both ends, obtained from a plastic water bottle. The inner part of the cylinder was lined with type "Bristol" yellow cardboard, by rolling up a 100 per 300mm rectangle fixed by two clips. Both bases were closed with square tulle mesh (1.4 mm openings), about 150 mm inside, secured with rubber bands. The cages were kept vertically resting on a base. A water dispenser, containing cotton wool with a plastic cover

(half petri dish), was placed on the tulle netting at the top of the container. The unit was put on a tray covered with paper towels to absorb excrement.

Food consisted of honeybee pollen loads. About fifty pollen loads, weighing more or less 300 mg, were put on the bottom of the cage. Water was supplied by dampening the cotton in the dispenser, making sure that the water did not drip down. Every unit hosted no more than four lacewing pairs. The females laid eggs both on the paper and on the tulle netting.

The maintenance of the adult rearing unit took place twice a week. Eggs were isolated as necessary in order to obtain larvae both for experimental purposes and to renovate the laboratory colony. The egg surplus had to be destroyed in order to prevent hatching and subsequent attacks of larvae against adults. With the same interval of time, twice a week, the pollen was renewed and the cotton refilled with water. The cotton, tulle netting and paper towels were substituted at regular but longer intervals.

An experienced technician can easily manipulate the adults by transferring them into a glass tube during rearing unit maintenance, otherwise, with caution, it is possible to anaesthetise them (Loru et al., 2010).

LARVAE REARING

Larvae were reared individually in order to avoid cannibalism. We used transparent, plastic, cylindrical containers both 25mm in height and in diameter with a plastic lid. The eggs were isolated by cutting the cardboard or tulle on which they had been laid and were put singularly into the containers using tweezers. As food we used mealworm beetle larvae (the Coleoptera Tenebrionidae *Tenebrio molitor* Linnaeus, 1758) previously killed with ethyl acetate. Also a drop of fructose solution was provided to the newly-hatched larvae (Pantaleoni, 2014). Different lacewing larvae instars were fed on mealworms of the appropriate size, in particular 4–5 mm long and 0.5–1 mg in weight vs 1st instar, 6–8 mm long and 2–4 mg in weight vs 2nd instar, 9–12 mm long and 6–12 mg vs 3rd instar. Nevertheless an expert technician is perfectly able to sort them by eye. Three mealworms were given to each lacewing larva twice a week and every time residues of the previous meal were eliminated. Initially a

little piece of paper towel was put into the container in order to absorb exudates from dead mealworms and offer a suitable support during cocooning. When the cocoon was about one week old, the residues of its last meal were eliminated. At the same time a 30mm high piece of "Bristol" cardboard was put into the container in order to provide support for pharate adults and facilitate adult emergence. Adults which had just emerged were sexed and put into the container described above.

DISCUSSION

Our adult rearing unit (Fig. 1) can be easily assembled by anybody. All the components derive from common cheap materials and a few simple tools such as scissors, a paper cutter, a ruler, a set square and a pencil are needed. Only the cap of the water dispenser is a specialized laboratory item (half of a petri dish), but this is also easily replaceable. Neither individual containers nor possible communal cages for larvae have been developed although there are many opportunities for improvement.

The replacement of a liquid meridic diet for adults with a solid oligidic one, such as pollen loads, is the main simplification of our method. According to our experience the management of a liquid yeast-fructose diet is laborious. This diet requires frequent cleaning or changing of the dispenser. It is both rapidly perishable and filthy, insects often get themselves dirty becoming incapable of flying or even moving. On the contrary pollen loads are clean, easy to give and to remove and more durable. In nature adult lacewings are essentially pollen-feeders and pollen, as stated by Nordlund et al. (2001), has good nutritional qualities. Moreover adult lacewings harbour mutualistic yeasts (*Turolopsis* sp.) that synthesize essential amino acids which are missing from their diet (Hagen et al., 1970). The pollen loads contain these yeasts, collected in the environment by bees (Gilliam, 1979). The slight disadvantage of using pollen is the dramatic difference in quality of the various kinds of pollen derived from different plants (Nordlund et al., 2001).

Just as the pollen-feeder habit of adults drove us towards our choice of pollen loads, the occasional scavenger habits of lacewing larvae (repeatedly
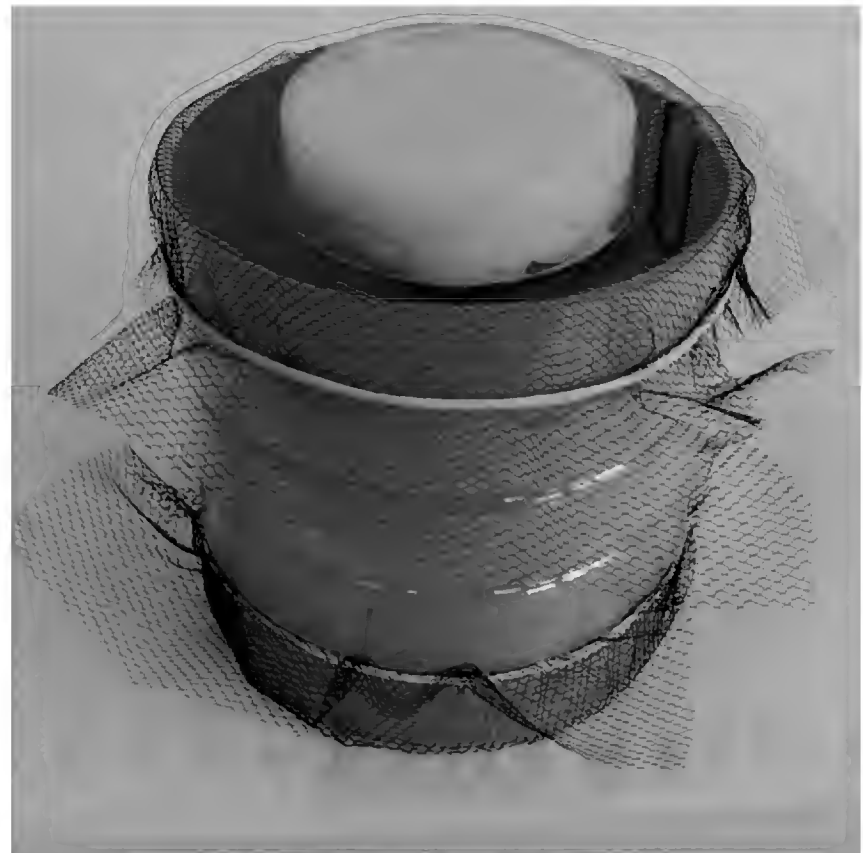

Figure 1. Adult rearing unit.

observed in nature by one of us (RAP), made us choose the killed mealworms. The use of *T. molitor* as factitious prey for lacewings was reported for the first time at the IX International Symposium on Neuropterology held in Ferrara, Italy, in 2005, but it remained unpublished. Since then, only Pappas et al. (2007) tested mealworms as a prey for lacewings, but using "second instar mechanically injured" instead of killed larvae of a larger size. Although the aim of the paper was completely different, and the use of *T. molitor* as factitious prey was not even cited, Loru et al. (2010) published the same kind of data. Pappas et al. (2007), rearing a species of *Pseudomallada* (then *Dichochrysa* Yang, 1991), found a short lifespan and low female fertility in specimens fed with mealworms. Loru et al. (2010), rearing a species of *Chrysoperla*, found a much longer lifespan (max 120 days vs max 45 days) and a higher fecundity (recalculated in order to compare the two papers) (about 650 eggs/female vs 192).

The great advantages in the use of mealworms as factitious prey are the minimal physical space required for their rearing, their high conversion efficiency, their potential for massive production and the chance to use organic waste materials as a food source (Ramos-Elorduy et al., 2002).

The future of biological control in agriculture will be played in two different arenas: the enhancement of "big" technology (biotechnology, industry, worldwide market) to apply to large scale produc-

tions, and the increase of "sustainable" technology to apply to local development policies. In both cases, the lacewings will be able to give a little help as beneficial through their mass production or their conservation by means of habitat management, but in any case we should be able to rear them.

ACKNOWLEDGEMENTS

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Preface

Studies on extant and fossils astriclypeids (Echinoidea Clypeasteroida)

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This monographic volume is the result of the need to clarify the diagnostic characters that really distinguish species and genera belonging to this interesting family of clypeasteroids.

In particular, during the research on the Oligo-Miocene species of *Amphiope* L. Agassiz, 1840 present in numerous outcrops of Sardinia (Stara et al., 2012; Stara & Borghi, 2014) have been reported several difficulties in specific distinction, when was using only the set of morphological and morphometric data normally used in the past (see Philippe, 1998).

As already observed by Durham (1955), almost all of the authors prior to his monograph on clypeasteroids were limited to the description of a few morphological and/or morphometric data, such as length, width and height of the test, petal-length and distance stoma or periproct from the anterior or posterior margin; all data disconnected from the plate pattern of the shell and often described by adjectives.

This practice, unfortunately, left many uncertainties, as is clear from the discussion that lasted for over a century (see Stara & D. Fois, 2014, and references therein). In fact much has been discussed on several morphotypes belonging to the genus *Amphiope* rather than *Echinodiscus* Leske, 1778, only on the basis of shape of their lunules.

The discussion, in fact, concerned about the usefulness of the shape of the two posterior lunules (ellipsoidal elongated along the axis of the rear ambulacra, or rounded to ellipsoidal transverse to the rear ambulacra) in the diagnostic applied to the systematic.

Philippe (1998), studying the *Amphiope* populations from the Rhône Basin of South-Eastern France, and highlighting the great variability of shape and size of the lunules in the examined individuals, placed in synonymy with *Amphiope bioculata* des Moulins, 1837, all nominal species previously established in its and in other peri-Mediterranean regions (except *Amphiope boulei* Cottreau, 1914).

To make matters worse, at the current state of historical research, several specimens used by the authors as type-species, are nowhere to be found, poorly defined and with stratigraphic data absent if not conflicting (for *Amphiope*, for example, see des Moulins, 1835–37; L. Agassiz, 1838–41; Cottreau, 1914, Philippe, 1998).

The generic distinction, however, is made easy since Durham (1955) published the plate patterns

of two specimens that have been a type-function, widely diffused by Smith & Kroh (2011) and used by various authors, such as eg. Jansen & Mooi, 2011.

As admitted by Philippe (1998), given the many uncertainties arose because of the supposed wide variability of lunules in *Amphiope*, it would be necessary to examine some sample of extant *Echinodiscus*, the genus closer to *Amphiope*. From this correct observation we started to plan the work that led to the publication of this monograph.

One of the main tools used in this study was the examination of the plate pattern and internal structure; to determine the usefulness and reliability were examined more than 100 samples of *Amphiope* from different Sardinian's sites, including more than 40 samples from a single locality (*A. lovisatoi* Cotteau, 1895) (Stara et al., 2012; Stara & Borghi, 2014) and more than 60 extant and fossils "*Echinodiscus*" from many other locality (Stara & Sanciu; Stara & M. Fois, 2014).

In particular, we have examined the plate pattern by more than 30 samples of "*Echinodiscus* cf. *auritus*" (Stara & M. Fois, 2014) from Mangili, Province of Tulear (Madagascar). Of these, the plates are numbered and have performed the necessary checks of the stability of the encountered characters.

The result of the research summarized in this monographic volume has exceeded all expectations and has allowed us to develop the tools to be used for generic and specific distinction of echinoids belonging to this family.

Meanwhile, it became clear that the variability of the lunules was not the real problem, since Stara & Borghi e Stara & Sanciu (2014) were able to differentiate between different species (some of them with a very high variability of lunules) of Sardinia and many other locations.

Overcoming these issues is also fundamental to achieve one of our main goals: to understand what were the relationships that these populations have had with the congeners of other regions of the Proto Western Mediterranean (Stara & Rizzo, 2013; Stara & Rizzo, 2014) .

Now we can propose, as a main tool for description of recent and fossils echinoids, analysis of the plate pattern of the test and in particular those of the oral interambulacrum 5 and oral / aboral ambulacra I and IV.

In the case of fossils from different geological epochs, with the same plate pattern, is also proposed the analysis of the internal structure, since that, as observed by Stara & Borghi (2014) with the elapse of geological times, the structure shows significant changes.

The trend shown by the sample of Sardinia (over 100 specimens of *Amphiope*) indicates a progressive reduction of the plates number and a lightening of the structure of the internal supports system.

The introduction of simple indices used for the recognition of the shape (Shape Index) and the size of lunules (Width Index) in *Amphiope*, as done by Stara & Sanciu (2014), for example, allowed to further differentiate groups of populations apparently similar. The use of other data before overlooked such as the measure within the ambitus of the interambulacrum 5 (Width at Ambitus) and the overall length of petalodium (Petalodium Length) facilitated further discrimination between genera and species. Finally, when the number of samples available makes it possible, can not miss the statistical analysis, as is done by Stara & Borghi (2014).

Other characters, such as the difference in the shape and size of pedicellaria are certainly important in supporting the distinction between species and varieties, but never separately from the analysis of the characters previously underlined. The use of these tools has made possible the distinction of two new genera and two new species within the family Astriclypeidae Stefanini, 1912, and has allowed us to lay the basis for the recognition of further differentiation.

It was possible to achieve this work, thanks to the availability of the web. The rapid access to relevant documents, before traceable only in few and far libraries; the ability to instantly contact other researchers around the world and to get such important information in real time; the possibility of obtaining original photos of animals and places in which examine the characteristics otherwise unreachable and geographic data such as, eg., topography, vegetation type, type of coasts, altitude of the mountains, has made it possible to multiply a hundredfold the potential at our disposal. And has certainly facilitated the realization of this work.

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Dispute about *Echinodiscus* Leske, 1778 and *Amphiope* L. Agassiz, 1840 (Echinoidea Astriclypeidae)

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ABSTRACT   Between the late 1800s and early 1900s, some European echinologists gave rise to a dispute over belonging to the genus *Amphiope* Agassiz, 1840, rather than *Echinodiscus* Leske 1778, of some lunulate scutelliforms present in the Oligocene-Miocene deposits of France and Italy. The problem has never been resolved, due to the fact that these echinologists considered the similarities or differences in shape, rather than structural ones. One of the nodes of the dispute was the variability in shape and size of the lunules in *Amphiope*. Because of all these problems, and also because of the impossibility to obtain and examine the structures of some type specimens of several species established in the past, the recognition of new species is very complicated and research carried out so far, in many cases is doubtful or controversial.

INTRODUCTION

The problems that have constituted the nodes of the dispute which we summarize here, have been the starting point for the studies carried out by different authors (see Stara, 2014). In particular, the frequent lack of references relating to the structural characteristics of *Amphiope* L. Agassiz, 1840 and *Echinodiscus* Leske, 1778, so far established, and the uncertainties due to the impossibility of comparing the type specimens of these species, have greatly complicated these studies.

It should be said, however, that L. Agassiz (1838-41), for example, had already meticulously illustrated the complete plating of the two faces of a specimen of *Lobophora aurita* (*Echinodiscus auritus* Leske, 1778) and that Lovén (1872) published an important work on the structure of echinoids.

With regards to the clypeasteroids, in particular, Durham (1955) systematically had reproduced patterns of the plates (plating) of a large number of species, including those of *Echinodiscus bisperforatus* Leske (1887) and *Amphiope bioculata* (not des Moulins 1837 type). Later, however, except in rare cases (Kroh, 2005; Pereira, 2010) no one, to our knowledge, reported platings of several other nominal species belonging to the family Astriclypeidae Stefanini (1912).

To try to end the dispute which we summarize here, other authors (Stara & Rizzo, 2014; Stara & Fois M., 2014; Stara & Sanciu, 2014) proposed a review of the main characters of some species belonging to this family (Astriclypeidae), using the plate pattern of their tests, considering this the main tool for the specific and generic diagnosis in echinology.

THE DISPUTE

Shape of lunules, uncertainly of the generic attribution and phylogenesis

Cottreau (1914), describing *Amphiope boulei* Cottreau, 1914 from the Aquitanian of Carry (Bouches-du-Rhône, France), stated that the axial lunules are a primitive morphological character in *Amphiope*. This primitive morphological character is already present in some Oligocene species, such as *Amphiope agassizi* des Moulins (1837) from the Asterias-limestone of the Bordeaux Region, *A. pedemontana* Airaghi, 1899, from Piedmont and Liguria (Airaghi, 1899) and *A. duffi* Gregory, 1911, from Cyrenaica. According to this author, the axial arrangement of the lunules persist in present-day species of *Tretodiscus* [currently considered as synonymous to *Echinodiscus* (Kroh, 2012)] bearing elongated lunules or slits notches on the posterior margin. These would be derived from Oligocene species of *Amphiope*, and they were considered the true *Echinodiscus* by Stefanini (1912).

According to Cottreau, also *A. fuchsi* Fourtau (1901), from the Middle Miocene of Siwa (Siouah), Egypt, was an *Amphiope*, as well as *A. boulei*, while "*Amphiope*" bearing elongated lunules was not the typical form. As evidence of the kinship existing between *Amphiope* and *Echinodiscus*, Cottreau observed that juvenile individuals in *Amphiope bioculata* des Moulins, 1837 (the type species of this genus) often bear pear-shaped elongated lunules along the axis of the rear ambulacra. According to this author, *A. cherichirensis* Gauthier, 1957, from Tunisia and *A. truncata* Fuchs (1883) from Middle Miocene of Egypt, can be derived from the Oligocene European "*Amphiope*" bearing axial lunules. These would be derived from Middle Miocene Indian echinoids, such as *A. placenta* Duncan, 1885, *A. desori* Duncan et Sladen 1883, *A. duncani* Lambert, 1907 and from Japanese ones, such as *Echinodiscus formosus* (Yoshiwara, 1901). The latter one would be the true ancestor of *Tretodiscus* (*Echinodiscus*), which has slits and is typical of the Indian Ocean, where it is represented by *Tretodiscus elongatus* Duncan et Sladen, 1883 and *E. bifissus* Agassiz (*Lobophora*) 1840, the latter one corresponding to the living *Echinodiscus auritus* Leske, 1778 with open slits on the back edge. Comparing the internal structure of "*Amphiope*" bearing axial lunules with

that of the typical *Amphiope* (*A. bioculata* des Moulins, 1835), Cottreau discovered that the two structures were identical, but unfortunately, he did not publish detailed descriptions of them.

Lambert (1915) wrote "Cottreau considered *Amphiope agassizi* as a very particular form, that joins very closely *Amphiope* to *Lobophora*, (actually *Echinodiscus*), and he proposed the suppression of the latter genus. (...). The *Amphiope* (morpho) type appeared in the Middle-Early Oligocene with *A. pedemontana*, and it bearing elongated lunules in the direction of the ambulacral axis, and retained this character in a series of successive species: *A. agassizi* in the Stampian (Middle Oligocene), *A. cherichirensis* and *A. baquiei* in the Burdigalian and *A. truncata* in the Early-Middle Miocene. Two branches detached from this main trunk: the first one in Aquitaine (France) during the Aquitanian, with *A. ovalifora* and the series of closely related Burdigalian and Serravallian species extinct in the Tortonian with *A. lorioli*. The second one, developed in the Indo-Pacific region, firstly appeared during the "Helvetian" with *Tretodiscus elongatus*, that clearly represent an ancestral form of the present-day *T. laevis* (A. Agassiz, 1872-74), *T. biforis* (Gmelin, 1778) and *T. rumphi* Lambert et Thiéry, 1914. Thus, the latter one does not descend from the Miocene European *Amphiope*, but it directly descended from the Oligocene *T. elongatum* through a succession of intermediate Indian forms."

On the variability of lunules

Cottreau (1914) examined the variability of the *Amphiope*'s lunules, using a sample from the Burdigalian of Saint-Cristol (Nissan, Hérault, France). He demonstrated their large variability in shape and size, and thus considered these characters not as diagnostic. He asserted that, despite the lunules are rounded or broadly oval in transverse direction in the adult specimens, *A. bioculata* could have elongated lunules in the direction of the posterior ambulacra in the juvenile stages, as well as adults of *A. baquiei* Lambert, 1907. Cottreau justified this apparent anomaly by the replication of ancestral characters in very young individuals.

More recently, Philippe (1998), based on the hypothesis of a wide intraspecific variability of the species of *Amphiope* from the Miocene of the Rhône Basin (France), tried to order the systematics

of this genus, synonymyzing a number of species, and maintaining only two valid taxa: *A. bioculata* and *A. boulei.*

DISCUSSION

Unfortunately, Philippe (1998) didn't consider important aspects, such as the internal test structure and the test plating. Those features were partially described by Durham (1955), Kroh (2005) and Pereira (2010). However, the material studied by Philippe did not come from the type locality indicated by des Moulins (1837) (Souze-la-Rousse). The Rhône Basin could even be considered the typical area, but the stratigraphical range of the sediments cropping out in this area is wide and the age of the holotype of *A. bioculata* was not indicated by des Moulins (1837). Additionally, the holotype of *A. bioculata* seems to have been lost [given that the type established by des Mulins (1837) belonged to his own collection (Meo Museum) and being that des Moulins lived in Bordeaux, we asked at the the local Natural History Museum if in their collections there are the Des Molulins collection. But we had no answer] and no description or illustration of its internal structure, or plate structures have ever been provided. Subsequent interpretations are highly controversial (see Agassiz L., 1838-40; Cottreau, 1914; Philippe 1998), thus leading to an uncertainty in the systematics of the genus. This problem and the need to assess the real extent of the intraspecific variability of the species of *Amphiope* comparing it with the living *Echinodiscus* species, are emphasized by Stara & Borghi (2014) during the revision and characterization of the *Amphiope* Sardinian's species, and they're emphasized by Smith & Kroh (2011), who recommended a systematic review of the entire genus. Finally, this problem has been analyzed by Stara & Fois M. (2014) on the bases of an *"Echinodiscus"* cf. *auritus* sample.

On the other hand, with regard to other *Echinodiscus* species, illustrations and descriptions made in the past (except Durham, 1955) concerned only shape and basic test measures. Today, it is demonstrated that the only basic measures, such as Test Length, Test Width and Test Height, are not sufficient to establish the real belonging to a species, rather than another, since different species have

been grouped under a single morphotype who answered to the name of *Echinodiscus*. For example, let's take two cases: the description given by L. Agassiz (in Agassiz & Desor, 1847) in the text where he established the species *Echinodiscus tenuissimus* from Waigiu (Western Papua, Indonesia) and the description of *E. tenuissimus in* Dollfus & Roman (1981), in his publication on Red Sea echinoids. In the first L. Agassiz says only that the species has two small lunules back, but does not contain any illustration concerning the test plating; Dollfus & Roman, however, states only that *"La var.* tenuissima *(Ag. & Desor, 1847)* =E. laevis *Al. (Ag. 1873), considérée par Mortensen (1948 d, p. 411-413) comme espèce séparée, n'existe pas en mer Rouge (pl. 33, fig. 5-6). Elle diffère d'auritus typique surtout par la position de l'anus (qui est sur la ligne joignant les milieux des lunules) et ses lunules fermées".*

"*The var.* tenuissima *(...). Herself differs from typical* auritus *for the position of the periproct (which is on the line that joins the half of lunules) and by closed lunules."*

Regarding *Echinodiscus bisperforatus* var. *truncata*, however, they show at least two morphotypes (coming from diverse countries as Papua New Guinea and Zanzibar) and a long synonymy, based on the shape of the test and of the lunules (short or long). This morphotype, in fact, had already been well illustrated by L. Agassiz (1838–40, pl. 11, figs. 11–16) as *Lobophora truncata*, (unknown origin) that differs from *L. bisperforata* by shorter lunules.

It is evident that, in the absence of platings description, regarding the specimens studied by several authors mentioned in the synonymy, it is impossible to understand what the authors refer to, when they talk about *Echinodiscus tenuissimus* and/or about *E. bisperforatus* var. *truncata.*

From Dollfus & Roman (1981): analyzing the beautiful images that illustrate the specimen from New Caledonia, in which the plating is partially visible, it can be observed that the plating is not characteristic of *Echinodiscus*, as will be illustrated best in Stara & Sanciu (2014). Other specimens, such as *Echinodiscus bisperforatus* var. *truncata* figured in pl. 34, figs. 3–4, coming from New Britain (Papua New Guinea) or as *E. bisperforatus* var. *truncata* figured in pl. 35 figs. 1–2, coming from Zanzibar, they differ in test shape and lunules length, but it is not clear what is their plating.

CONCLUSIONS

It is evident that, in the absence of careful plating analysis, it is not possible to determine the membership of these specimens to one species/genus rather than to another. We believe that the analysis of the structure and in particular of the plating in echinoids is the primary tool for diagnosing and that is very difficult to confirm old descriptions based only on morphology.

Therefore, to analyze the specimens of the family Astriclypeidae, in this volume will be studied most importantly their plating.

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Paleogeography and diffusion of astriclypeids (Echinoidea Clypeasteroida) from Proto-Mediterranean basins

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ABSTRACT   In this paper, the authors retrace the geological changes that during the Neogene have modified the paleogeography of the Western Mediterranean up to its current set-up. It is assumed that migration and probably also speciation of the involved astriclypeids (particularly *Amphiope* L. Agassiz, 1840 and *Echinodiscus* Leske, 1778) are closely related to those changes.

KEY WORDS   Paleogeography; Astriclypeidae; Oligo-Miocene; Mediterranean Sea.

INTRODUCTION

Currently we are dealing with investigations on the Miocene echinoids of Sardinia and their relationship with the echinological paleofaunas that during the Cenozoic have migrated from, or towards, the Proto-Mediterranean seas. In particular, great attention is given to the genus *Amphiope* Agassiz, 1841 (family Astriclypeidae Stefanini, 1912), which is common in the Oligo-Miocene marine deposits of Sardinia (Comaschi Caria, 1955; Stara et al, 2012; Mancosu & Nebelsick, 2013; Stara & Borghi, 2014) and its relationship both with congeners of peri-Mediterranean regions and the phylogenetically closest genera such as *Echinodiscus* Leske, 1778.

The clypeasteroids appeared at the end of the Mesozoic or in the early Cenozoic. According to Smith (2001), the oldest clypeasteroid genus is *Togocyamus* Oppenheim, 1915, from the end of the Paleocene of Senegal, Togo and Nigeria. It is assumed that they evolved from the cassiduloids,

which were already present in the Maastrichtian, at the end of the Cretaceous or in the early Paleocene, and then spread and diversified through the world oceans (Smith & Kroh, 2011). The large number of fossil records from the Eocene of United States, Europe, Middle East, Taiwan, Japan and Africa, confirms this wide diffusion and diversification of clypeasteroids, raising doubts as to whether all this could have happened in a tens of millions of years as assumed by Kier (1982). Wang (1984) argued that *Echinodiscus tiliensis* was already present in the late Paleocene or early Eocene in Taiwan, although the remains of this species were poorly preserved and their stratigraphic occurrence was uncertain. Because of paucity of the fossil record available for study, the discussion on the phylogenetic position of many of these fossils is still open.

Many genera of clypeasteroids lived in the Proto-Mediterranean and/or peri-Mediterranean basins, from Eocene to Miocene, as *Sismondia* Desor, 1857, *Clypeaster* Lamarck, 1801, *Scutella* Lamarck, 1816,

Parascutella Durham, 1953, *Amphiope* L. Agassiz, 1840 (Cottreau, 1914; Smith & Kroh, 2011); few of these survived there until the Pliocene, such as *Clypeaster* (Giannini, 1957; Cotteau et al., 1876-1891). In Sardinia, in particular, *Amphiope* appeared in the Chattian-Aquitanian and disappeared in the Tortonian-Messinian age (Comaschi Caria, 1955, 1972; Stara et al., 2012a).

Nowadays, a number of clypeasteroid genera inhabit wide areas that include environments ranging from tropical to temperate, with some species extending even further polewards, such as *Echinarchnius* Gray, 1825; they adapted to different ecological niches, with preference for the inter-tropical zone (Ghiold & Hoffmann, 1984, 1986).

Several members of the Astriclypeidae family, found the ideal habitat in more or less limited geographic regions. *Astriclypeus* Verrill, 1867 has been adapted from Oligocene to the present, in Japan, China and Cambodia seas (Smith & Kroh, 2011). *Echinodiscus* (herein assumed as a monophyletic group) spread from the Oligo-Miocene throughout the Indo-Pacific, as far as Australia and South Africa, including the Red Sea and the Persian Gulf; *Amphiope* and all other echinoids belonging to the family Astriclypeidae, are absent from the present Mediterranean Sea. Different scientists did not agree on the generic attribution of astriclypeids with two lunules aligned with the rear ambulacra, and about the size and shape of the lunules variability in *Amphiope* (Stara & D. Fois, 2014).

In the North-Western Mediterranean, *Amphiope* (bearing transverse or rounded lunules) is recorded from Chattian-Aquitanian to Tortonian–Messinian, and it occurs in about thirty localities of the Rhône Basin, south-eastern France (Philippe, 1998) and in other thirty sites of Sardinia (Italy) (Stara et al., 2012a; Stara & Borghi, 2014).

Furthermore, in the Tyrrhenian Basin *Amphiopeis* reported in Corsica (Cotteau, 1877) and in some Italian regions: Tuscany (Giannini, 1957), Campania (Barbera & Tavernier, 1989), Calabria (Cottreau, 1914, Carone & Domning, 2007; our observations) and Sicily (Garilli, 2010); further, to the West it is found in some regions of Spain [Barcelona (Lambert, 1928a); Valencia and Alicante (our collections); Mallorca and Menorca Islands (Llompart, 1983)] and Algeria (Pomel, 1887-1888; Cotteau et al., 1891). Along the Atlantic-European coasts *Amphiope* is reported in Portugal [Lisbon, etc. (De Loriol, 1896;

Pereira, 2010)] and in France [Aquitaine (Lambert, 1928b) and Touraine (our collections)]; along the Atlantic-African coasts *Amphiope* is found in Angola (De Loriol, 1905). To the East, *Amphiope* is reported in both the Central Paratethys [Austria and Hungary (Kroh, 2005)], in the eastern basins [Turkey (Nebelsick & Kroh, 2002)] and from the Middle East regions [Egypt (Kroh & Nebelsick, 2003), Arabia, Iraq (our observations) and Iran (Khaksar & Moghadam, 2007)] to the Indian coasts (Mooi, 1989). Atypical forms of "*Amphiope*" with axial lunules are mentioned, but they are less frequent and mainly consist of Oligocene species found in France [Aquitaine (Lambert, 1915)], Italy [Liguria-Piedmont (Airaghi, 1899, 1901), North Africa [Tunisia (Gauthier, 1899), Libya and Egypt (Gregory, 1911; Fourtau, 1899, 1904)] and in the Aquitanian of the Rhône Basin, France (Cottreau, 1914; Philippe, 1998). In the Miocene of some regions of the Middle East both forms are recorded (Kier, 1972) (Fig. 1).

NOTES ON THE EXAMINED ASTRICLYPEIDS ECOLOGY

The ecology and life styles of some clypeasteroids have been studied in the past: among others, Merrill & Hobson (1970) observed *Dendrasterex centricus* populations along the Pacific coast of California and Mexico; Kang & Choi (2002) studied a population of *Astriclypeus manni* from the Cheju island of South Korea, Nebelsick & Kampfe (1994) examined, from a taphonomic point of view, some populations of *Echinodiscus auritus* and *Clypeaster humilis* in the Bay of Safaga, Red Sea, Egypt. Kleitman (1941) observed that some clypeasteroids can live at temperatures ranging from 10°C to 30°C, with best conditions between 24°C and 26°C; Nebelsick (1999) observed that most species of astriclypeids lived in near-shore to infralittoral sandy environments, with high to medium-high wave energy and deep currents. The discovery of Pliocene fossils of *Echinarachnius* at Lituya Bay (North West Coast of Alaska) in the Arctic Circle, corresponding to 59° north latitude (Merte, 1930) and Late Miocene *Amplaster* and *Monophoraster* along the Atlantic coast of the Province of Chubu in Argentina, at 45°South (Martinez & Mooi, 2005), indicates that some clypeasteroids were and are able to adapt to significant differences in tem-
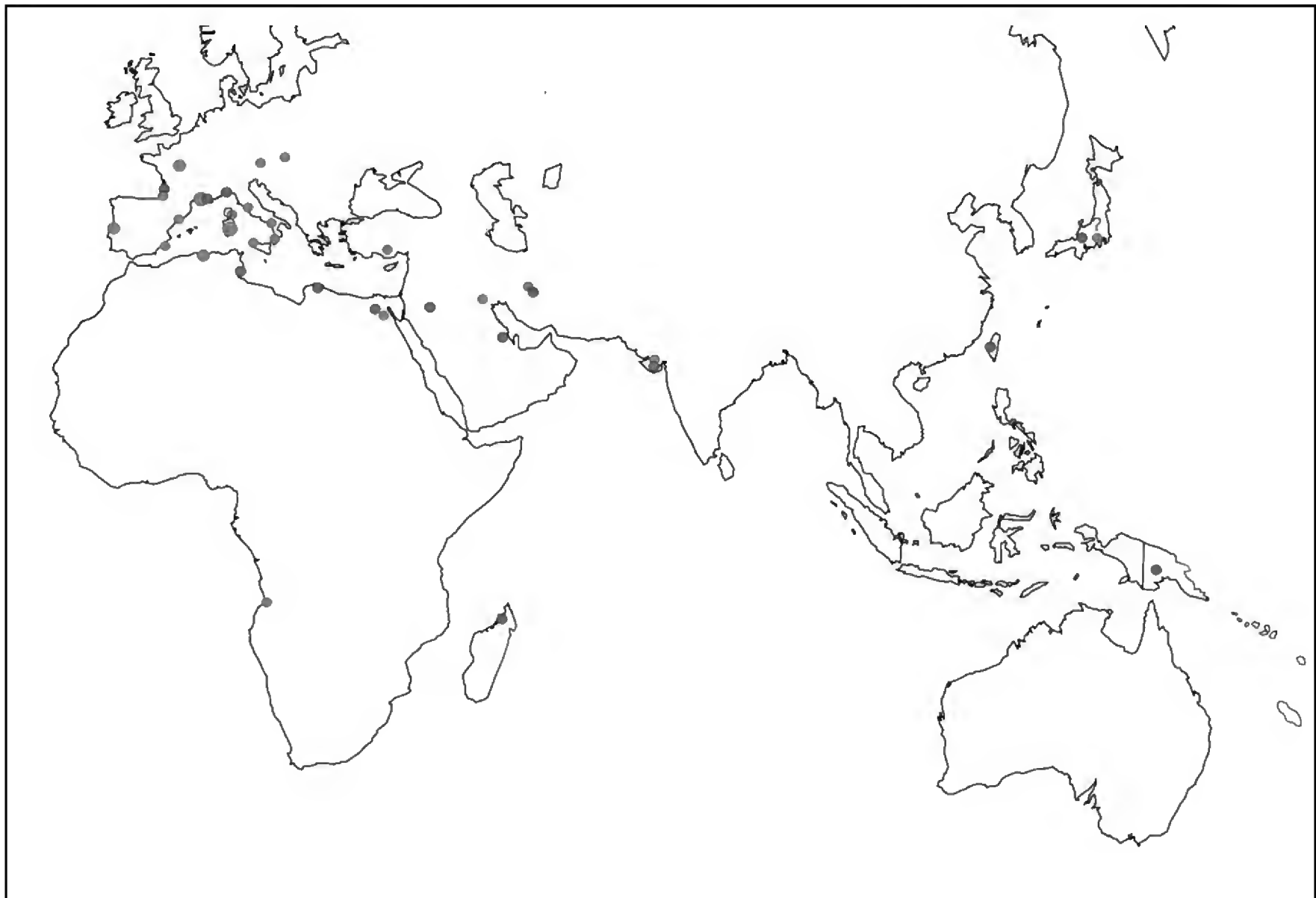
Figure 1. Oligo-Miocene distribution of the the main morphotypes.

perature and salinity conditions. Stara et al. (2012), comparing the sediments of 15 Sardinian sites of Miocene *Amphiope* with those of 5 present beaches observed that those populations live in environment characterized by sandy bottoms and shallow water.

As summarized by Kroh & Nebelsick (2003), *Mellita*, *Encope*, *Leodia* and *Echinodiscus* are all shallow borrowers, whereas *Dendrasterex centricus*, that maintains a partially exposed vertical position in the sediment is a suspension feeder (see Merrill & Hobson, 1970).

In particular, with regard to the bathymetric range of *E. auritus*, Dollfus & Roman (1981) observed it at 1–2 meters in depth in the Red Sea, but also dredged a number of specimens between 10 and 15 meters in depth; the samples studied from Bohol (Philippines), were collected at about 50 meters in depth and Mazzetti (1893) during the dredging session carried out in the Red Sea by the ship "Scilla" in 1891-92, at Goubet Soghra, collected several specimens between 40 to 100 meters in depth.

PALAEOGEOGRAPHY AND PHYLOGENETIC RECONSTRUCTIONS

In order to better understand the relationships between these echinoids, we need to reconstruct their migration pathways. As noted by Stefanini (1912), the "scutellidi" always spread in a relatively limited geographical area. We suppose that this fact depends on their lifestyles, linked to nearshore sandy environments.

Probably, their larval dispersal was not very wide and needed to find sandy bottoms near roosts. This seems justified by the fact that their spread seems to have proceeded along the coast or through basins of limited depth.

In the paleo-biogeographic reconstruction, however, one of the keystones is the completeness of the knowledge of the paleofauna of the period under study.

Unfortunately, as stated also by Harzhauser et al. (2007), only some areas have been deeply investigated and therefore are well known.

DIFFUSION OF THE ASTRICLYPEIDS FROM PROTO-WESTERN MEDITERRANEAN BASINS

An interesting contribution on the temporal and spatial distribution of "scutelliformes" was published by Stefanini (1912), who assumed that the North Ocean was a spreading center for these groups of echinoids, where several species were already present during the Eocene and Oligocene. A further contribution came from Cottreau (1914), who made a summary on the diffusion and evolution of echinoids (among others, also *Amphiope*) in the context of the Mediterranean Neogene.

By using the latest knowledge of geology and paleobiogeography, as we shall see later, it is possible to better define the temporal distribution of the two basic morphotypes, that are the main object of this study. The first is "*Amphiope*" and "*Echinodiscus*" with axial lunules (Figs. 2, 3), appeared during the Rupelian in Italy (Piedmont and Liguria), Libya and perhaps also in Tunisia, and subsequently diffused in the Middle Oligocene (late Rupelian-Early Chattian) of the Bay of Biscay (France). In the Aquitanian, a similar morphotype is present in the Basin of the Rhône and then in the Early Miocene of Tunisia, Libya, (Burdigalian) Egypt. In the Middle Miocene the diffusion area shifted decisively towards the East. There are no citations of this morphotype in the Western Proto-Mediterranean basins, along the Atlanto-European coasts (from the Bay of Biscay to down) and along the Atlanto-African coasts (Fig. 1).

The second morphotype, *Amphiope* with round or transverse lunules (Figs. 4, 5), appeared in the Chattian-Aquitanian in Sardinia and in the Aquitanian of France and Kabylies; it was widespread during the Miocene in the Western Mediterranean Basin, along the Atlanto-European and Atlanto-African coasts, in the Paratethys, in the Middle East, as for as India and perhaps to Japan (Fig. 1), and went extinct during the Tortonian-Messinian in Sardinia (Philippe, 1998; Smith & Kroh, 2011; Stara et al., 2012). Another morphotype (Fig. 6), characterized by small rounded lunules rather far from the petaloid tips (Fig. 7), firstly appeared in Libya during the Miocene; it showed some features of both the previous main morphotypes.

Echinodiscus cf. *auritus* (Fig. 3) is already widespread from the Gulf of Suez to the Indo-Pacific coasts in the Plio-Pleistocene. This morphotype is recorded in the Plio-Pleistocene of Suez (Fourtau, 1899), in the Isle of Kharak (current Khark Island) of the Persian Gulf (Duncan & Sladen, 1883) and of the Aru Islands in Indonesia (Currie, 1924), in the late Pliocene and Pleistocene of Java (Jeannet & Martin, 1937). Lastly, it appeared in Pleistocene-Holocene sediments near Hurghada (Red Sea, Egypt) accompanied by other forms of *Echinodiscus*. Lindley (2001) cited a similar morphotype characterized by axial and medium-sized lunules, in the Middle Miocene (Langimar beds) of the province of Morobe (Papua New Guinea), but he assigned it by mistake to *Echinodiscus bisperforatus*.

Currently *Echinodiscus* cf. *auritus* seems to be the astriclypeid with the widest spread surpassing the lines of the two tropics, 30°North to 35°South. Their presence is ascertained along the East African coast of Mozambique and South Africa and along the coasts of Madagascar. To the North it is ascertained along the Red Sea, to the Gulfs of Suez and Aqaba, (Dollfus & Roman, 1981) the Persian Gulf and along the northern shores of the Indian Ocean (Sakthivel & Fernand, 2014). Lastly, to the East, it is widespread in the Malay Archipelago (Indonesia), Thailand (Putchakam & Sonchaeng, 2004), Philippines, along the Gulf of Siam, China (Lane et al., 2000) and Japan, reaching the Northern and Western coasts of Australia and perhaps New Caledonia (Fig. 8).

Echinodiscus bisperforatus shows a similar distribution: it was present in the Middle Miocene of Makamby island, Northern Madagascar (Collignon & Cottreau, 1927) and in the Pleistocene-Holocene sediments of Hurghada in the Red Sea (our collections), but some morphotypes showing features similar to those of *E. bisperforatus* (*E. formosus* Yoshiwara and *E. yeliuensis* Wang), were maybe already present in the Middle Eocene and certainly in Miocene of Taiwan.

Finally, the "*E. tenuissimus*" group seems to have a limited distribution in northern latitudes of the Indian Ocean to Oceania, but today it would be absent from the eastern and southern coasts of Africa (Fig. 8).

In the reconstruction proposed by Stara & Rizzo (2013), the similarity between the echinoid faunas of North Atlantic and Western Mediterranean would have been facilitated by the opening of the pre-Pyrenean Corridor, which took place

between Middle Eocene and Middle Oligocene (Fig. 9), allowing direct exchanges between the Atlantic faunas of the Bay of Biscay and those of the Alpine Tethys or intra-AlKaPeCa basins (this is an acronym used by Bouillin et al. (1986) to indicate the micro-continent that moving away from the European plate, would have given rise to different regions of the actual Western Mediterranean). After the closure of the pre-Pyrenean Corridor, which probably has occurred during the Middle Oligocene, the two faunas began to differentiate.

In addition, the almost complete separation between the Alpine Tethys (from which the Proto-Western-Mediterranean was born) and the Western Neotethys basins (according to the reconstructions of Stampfli et al. (2002), or basins resulting from detachment of the AlCaPeKa micro-plates, according to Carminati et al. (2012), also justifies a lot of the differences observed between the Miocene faunas of the Western Mediterranean and of the Eastern Mediterranean (see Figs. 9-14). For example, in the first area, "*Amphiope*" with axial lunules and
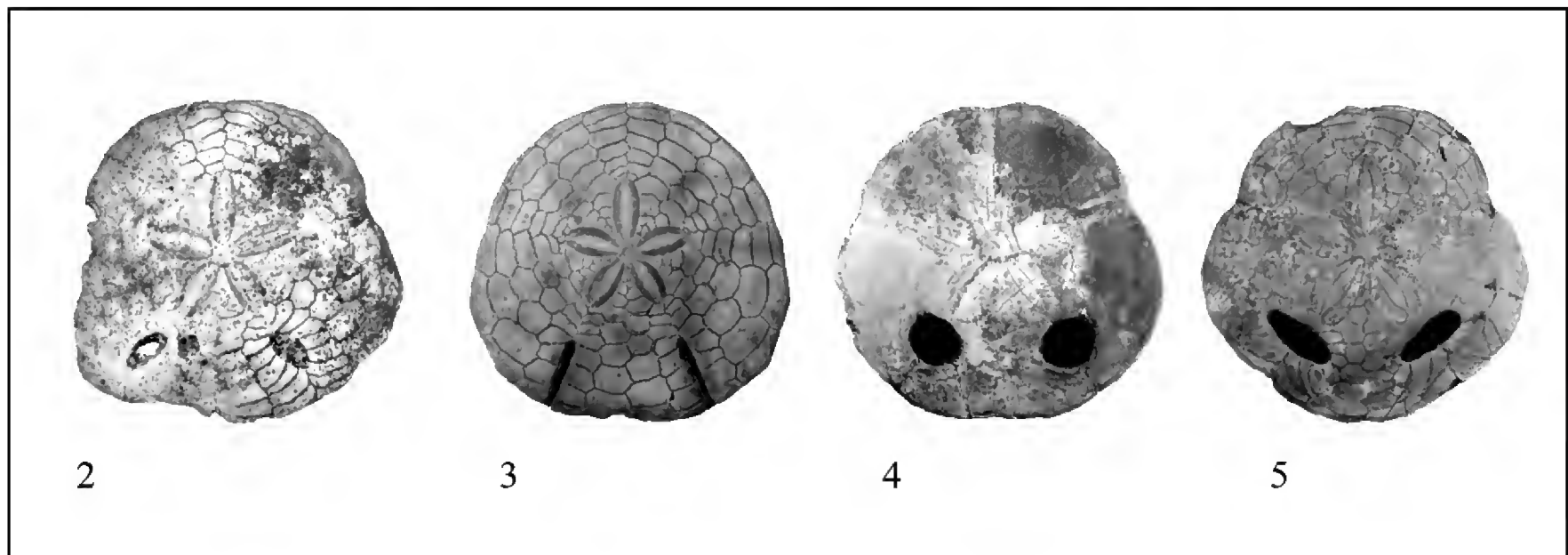
Figures 2–5. Morphotypes based on the shape of rear ambulacral lunules/slits. First morphotype, bearing axial lunules or slits notching the posterior margin: Figure 2. "*Amphiope*" pedemontana, Oligocene, Val Bormida, Liguria and Piedmont, Italy. Figure 3. "*Echinodiscus*"cf. *auritus*, Recent, Mangili, Tulear, Madagascar; Second morphotype, bearing rounded or transverse lunules: Figure 4. *Amphiope* sp., Oligo-Miocene, Duidduru, Sardinia, Italy. Figure 5. *A. nuragica*, Oligo-Miocene, Cuccuru Tuvullao, Sardinia.
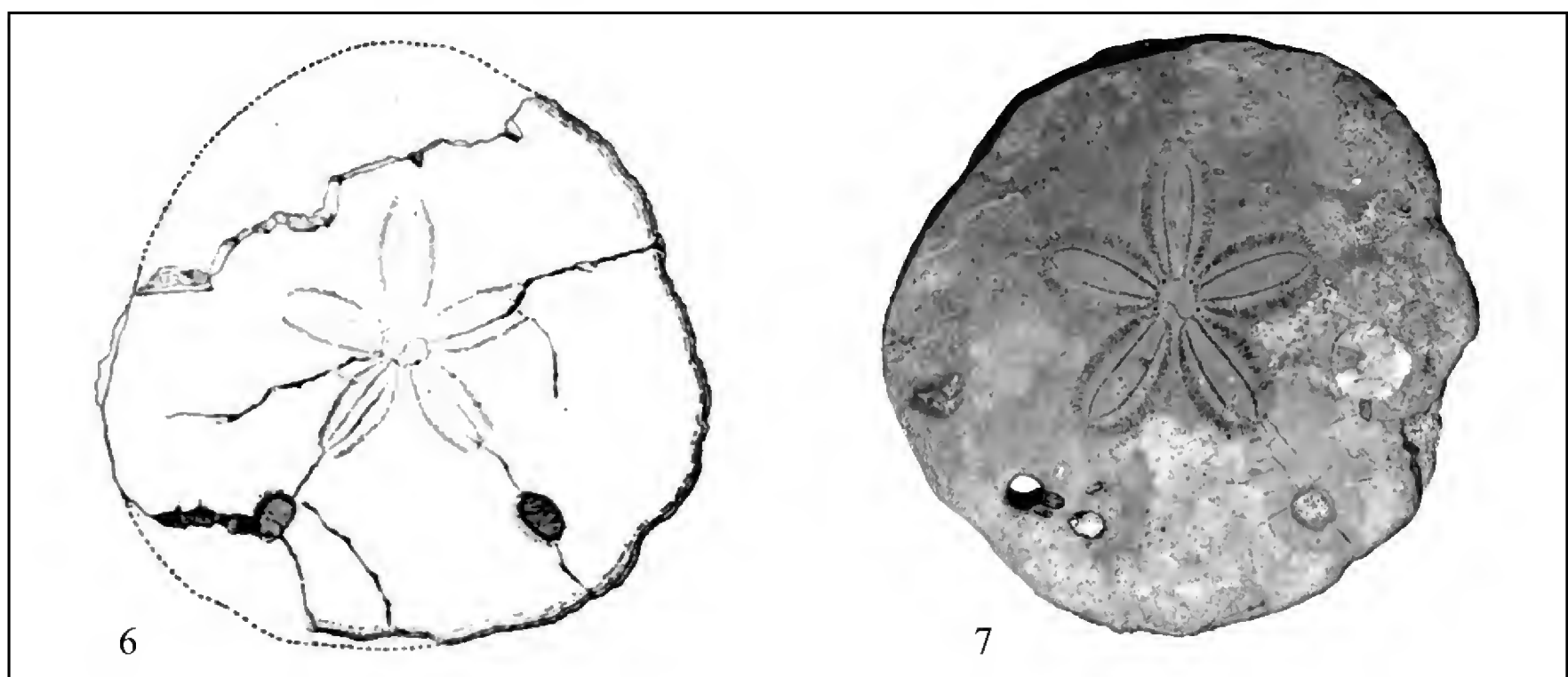
Figures 6, 7. Morphotype with small lunules far from the petal tips: 6 "*Amphiope*" *boulei*, Aquitanian, France (from Cottreau, 1914). Fig. 7. "*Amphiope*" sp., "Miocene", Libya (NMHUK collections).

Scutella were absent, whereas in the second area both these genera were widespread. Indeed, in the Western Mediterranean, only *Amphiope* and *Parascutella* are known (A. Kroh, personal communication, June 2012).

According to Stara & Rizzo (2013), from the Sardinian-Provençal basins, derived from the fragmentation of the micro-continent AlKaPeCa, at least three waves of migration of lunulate scutellids may have originated: two from the East and one from West. The first wave would have taken place during the Oligocene through the corridor of the Bormida Valley (Piedmont and Liguria) (Fig. 10), the second at the beginning of the Miocene, through the corridor of the Alpine Paratethys, the third was a result of the fragmentation, the detachment and their drift towards the south, of micro-plates, from the continental margin of the Ibero-Provençal crust.

The second of these migration has been already recognized by Kroh (2007), who stated that the majority of the echinoid fauna of the Central Paratethys is immigrant from the western Mediterranean and partly shows similarities with that of the

Atlantic region. This migration took place in three phases: the first wave would have started at the beginning of the Miocene from the Rhône Basin through the Alpine Tethys, the second and the third, much later, according to Kroh (2007) took place through the trans-Tethys Dinarids Corridor that led to the Adriatic Neotethys. Some species wich immigrated during the first phase had Atlanto-Mediterranean affinities, those joining the second and third phases were more closely related to the faunas of the Eastern-African coasts.

The migration along the Val Bormida Corridor has been hypothesized by Stara & Rizzo (2013), based on the presence of a series of *Scutella* and "*Amphiope*" *pedemontana* rich beds that crop out in the Rupelian of Liguria and Piedmont. The hypothesized migration is in accordance with the similarity of some characters that these "*Amphiope*" share with those of Rupelian from the coast of Libya and those of the Middle Oligocene (Late Rupelian-Early Chattian?) of the Gulf of Biscay. In addition, this step is also traced by the spread of *Heterobrissus* Manzoni et Mazzetti, 1878. This
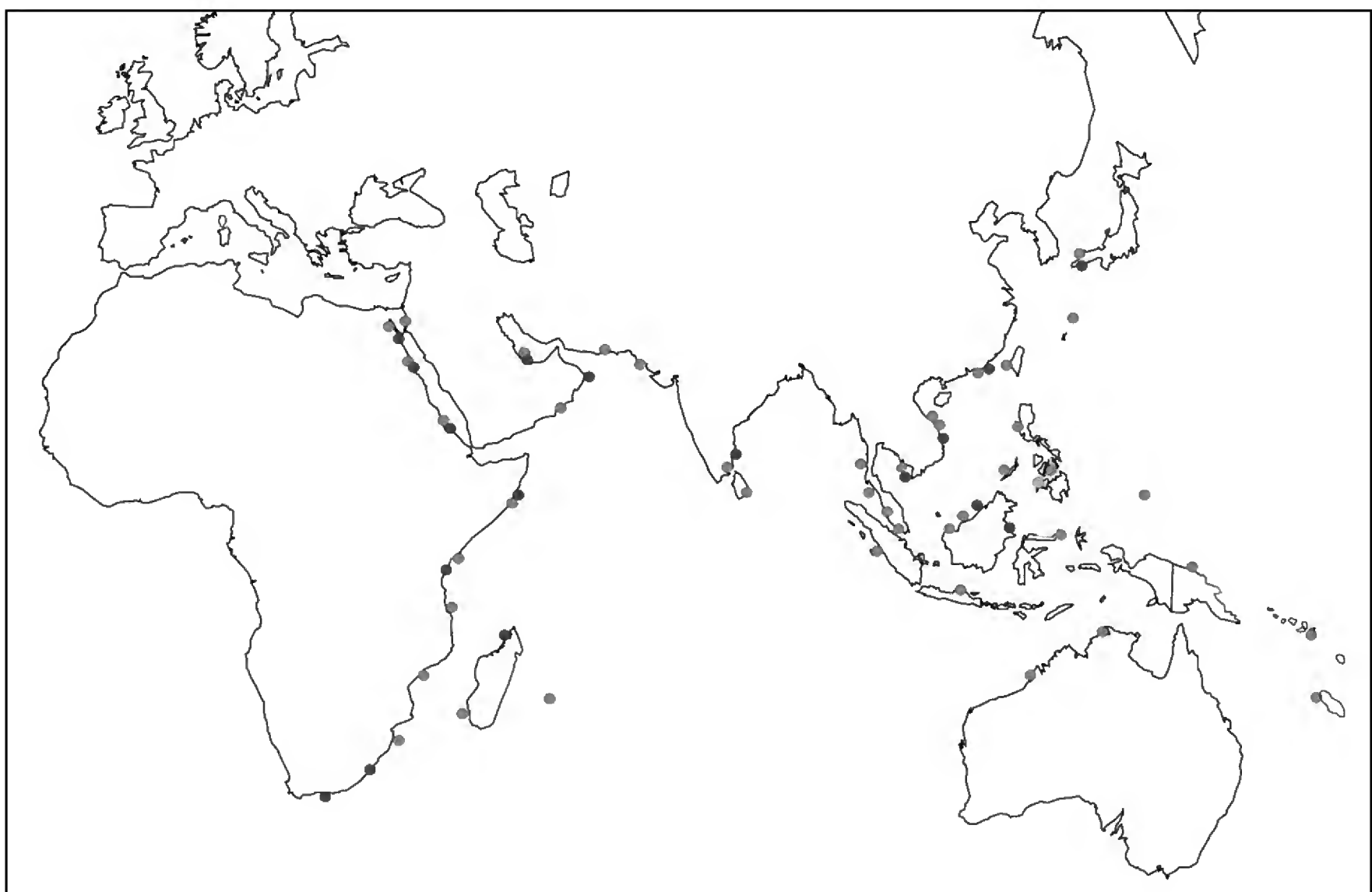

Figure 8. Distribution of extant main morphptypes of "*Echinodiscus*" genus. Yellow dots: "*Echinodiscus*" cf. *auritus* group. Green dots, *Echinodiscus bisperforatus* group. Orange dots: "*Echinodiscus*" *tenuissimus* group.
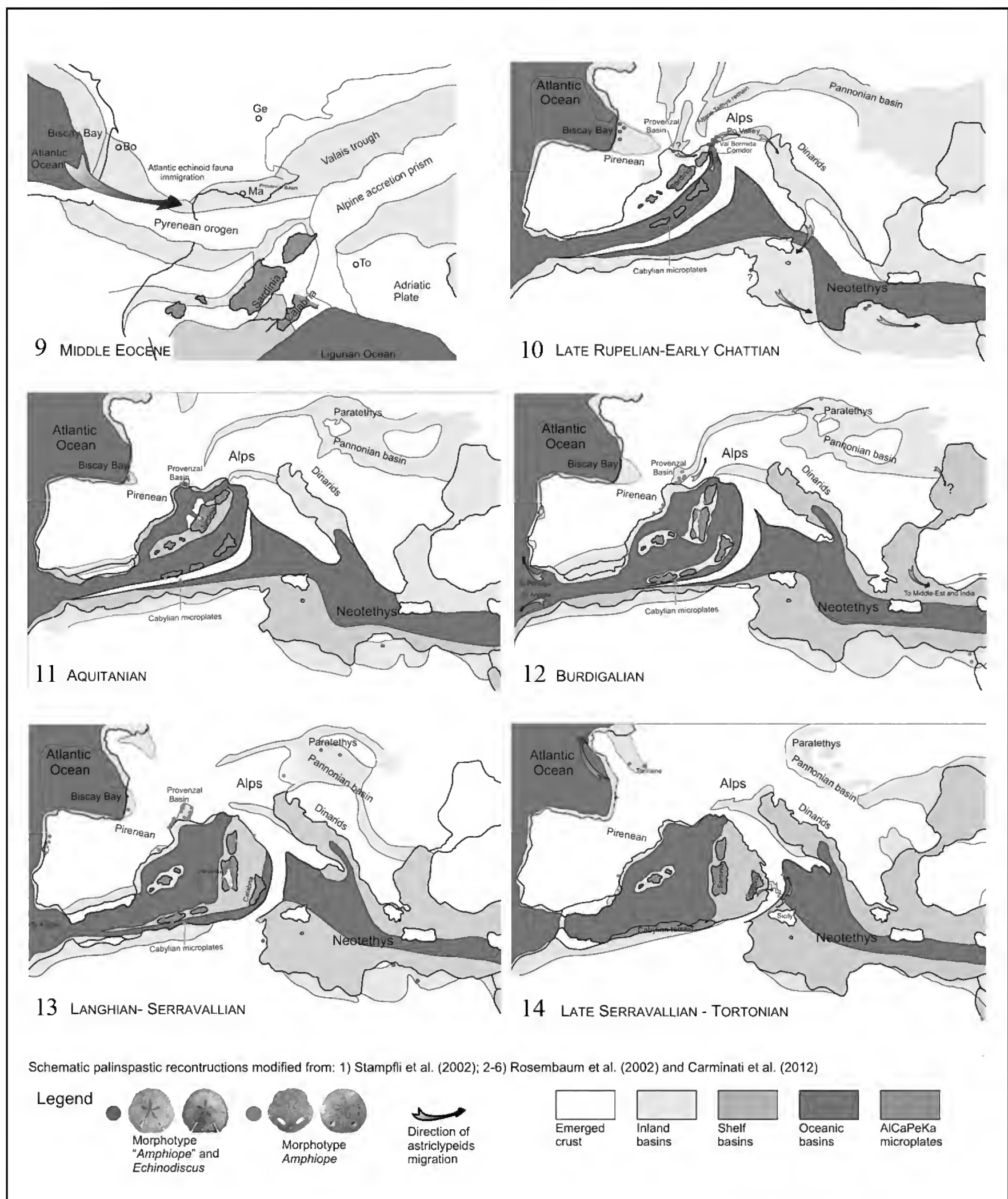
Figures 9–14. Time scanning of *Amphiope* diffusion in the proto-Mediterranean basins. Figure 9. Middle Eocene-Lower Oligocene connection between the Atlantic-Gulf of Biscay and the Provençal Basin. Figure 10. Morphotype 1 populations begin their eastward Oligocenic migration through the Val Bormida Corridor. Figure 11. Starting from a single distribution center, located between the Biscay and the original intra-AlCaPeKa basin, morphotype 2 populations begin their Oligo-Miocenic spread. Figure 12. Morphotype 2 is already widespread from Atlantic coasts to the far east; morphotype 1 is no longer present in the western basins. Figure 13. Morphotype 2 reaches its peak in the Rhône Basin and in Sardinia; morphotype 1 has spread from the Middle East to India. Figure 14. At the end of the Middle Miocene, morphotype 2 begin to extinguish, whereas morphotype 1 has colonized the Indian Ocean and the Western Pacific Ocean. Based on the paleo-geographic data from Stampfli et al., 2002; Rosenbaum et al. 2002; Carminati et al., 2012.

genus is present in the Oligocene of Caribbean Islands (Jackson, 1922), in the Early Miocene of Sardinia (Stara et al., 2012b), in the Middle Miocene of Emilia and San Marino (Manzoni & Mazzetti, 1878), lastly in the Serravallian of Cyprus (Currie, 1935; Smith & Gale, 2009), and today it is widespread in the seas of China and South Eastern Asia (Lane et al., 2000). So, the basins of the Middle East suffered at least two waves of migrants from N-NW, the first one through the Adriatic Tethys during Oligocene and the second one through the eastern Paratethys between the end of the Early Miocene and the Middle Miocene.

In summary, from the Late Oligocene to the Early Miocene, the Val Bormida Corridor had already closed as a result of Apennines orogeny, while the Alpine Tethys Corridor shut at the end of Burdigalian as a result of the Alpine orogeny. The closing of these two corridors led to the isolation or, at least, to a drastic reduction of the exchanges between the eastern and western faunas of the Tethys (or Proto-Mediterranean basins). This new situation probably allowed the differentiation of the Oligo-Miocene "*Amphiope*" with axial lunules from the North-African and Middle-Eastern coasts. During the Burdigalian, *Amphiope* with rounded or transverse lunules was already present in the central Paratethys and in Egypt. However, while it seems clear that it arrived in the Paratethys crossing West to East the canal north-Alpine, is not yet clear how it arrived in Egypt. In fact, there is no evidence of these echinoids, nor *Parascutella*, along the Miocene Adriatic and Ionian seashores, favoring the continuity of their migration through the eastern basins, already during the Middle-Early Miocene, to other marine faunas. In any case, as a result of their migration, *Amphiope* went to Turkey, Egypt, Saudi Arabia, Iran and finally to India and also in Iraq (our observations). Finally, Harzhauser et al. (2007) suggest that the complete disconnection between the Proto-Mediterranean basin and the Indian Ocean basin occurred at the end of the Burdigalian, when the two faunas where already differentiated.

The apparent diachrony should be clarified when the astriclypeids of the eastern regions faunas will be studied. In fact, it is possible that faunas from the West (as we assumed), but also from the East, met in the Middle East area, since different forms of "*Echinodiscus*" were already present (doubtfully) in the Middle Eocene, but certainly in

the Lower Miocene, respectively, in the islands of Taiwan and Japan.

Regarding the Mediterranean, according to Rögl (1998), during the Miocene the two sides of the Mediterranean were in full connection, while according to Stampfli et al. (2002), these were completely separate. Much evidence is needed, however, we argue in favor of this second hypothesis. The reconstruction made by Stampfli et al. (2002) suggests that the complete connection between the Eastern and the Western Mediterranean would have occurred much later, when the Calabrian microplate reached the Italian Apennines, at the end of the Miocene or during the Pliocene. Although the precise date of the disconnection between the basins of the eastern Neotethys and the Indian Ocean is still under discussion, Harzhauser et al. (2007) agree with the development of different biota for these two regions during the beginning of the Middle Miocene.

THE SPREAD OF *AMPHIOPE* WITH TRANSVERSE OR ROUNDED LUNULES TO THE WEST-SOUTH-WEST

In the North-Western Mediterranean sedimentary basin, Chattian-Aquitanian to Tortonian-Messinian fossils of *Amphiope* with rounded or transverse lunules have been found in many localities in the Rhône Basin (Philippe, 1998), and Sardinia (Stara et al., 2012a; Stara & Borghi, 2014).

In detail, starting from density of *Amphiope* deposits existing in a specific region, we can assume that *Amphiope* appeared in a fairly restricted area within the archipelago formed between the Basin of the Rhône and Sardinia, from the end of the Oligocene to the beginning of Miocene. According to Rosenbaum et al. (2002) and Gattacceca et al. (2007), in this period different microplates began drifting towards the South forming that archipelago (Figs. 11–14). The shift of these microplates to the current position point lasted about 7 million years, and during this time the fauna could (in some cases) differ from the original giving rise to new species, as it happened for example in Sardinia, where 3 species [*Amphiope nuragica* (Comaschi Caria, 1955); *Amphiope lovisatoi* Cotteau, 1895, and *Amphiope montezemoloi* Lovisato, 1911] were confirmed and for the first time,

another two new ones have been described (Stara & Borghi, 2014).

At the end of the Burdigalian the Sardinia-Corsica microplate had completed its route after an anticlockwise rotation, stopping more or less in its current position; Calabria located in the East of Sardinia, and it reached its current position only in the Pliocene, the Kabylies had almost welded with North Africa, the Betic-Rifian microplates were still in the Alboran Sea, while the Balearic Islands were more or less in the current position.

A part of Sardinia-Corsica and Balearic Islands now detached itself, the other microplates, each with its own specific fauna, to the contact with the North African margin (for example the Kabylies) or southern Europe (Iberia) were able to create further migrations, which most likely occurred along the sandy beaches adjacent to shallow depths (Stefanini, 1912).

Pomel (1883, 1887-8) and Cotteau et al. (1876-1891) reported the presence of *Amphiope* in the Early Miocene of Cherchell and in the Middle Miocene of Mléta, Oran, as well as in other places of Kabylies (Algeria). Most likely, as suggested by Stefanini (1912), starting from the Kabylies, *Amphiope* populations reached the Atlantic Ocean to continue towards South to colonize the area of Bom Jesus (Angola, West Central Africa) during the Middle Miocene. It is uncertain if the presence of *Amphiope* in the region of Alicante and Valencia during the Tortonian is due to a direct migration from the North, since its presence is also reported in the Middle Miocene in the region of Barcelona. It seems logical that, starting from the South of the Iberian Peninsula *Amphiope* has continued its coastal migration as far as the Atlantic Ocean and back along the coast of Portugal (Fig. 12). Pereira (2010) reports: "The echinoid fauna of mainland Portugal is closely related to that of the Mediterranean region. In fact, the biogeographic investigation of the Portuguese echinoid fauna shows that a major part of the Portuguese species is composed by Portuguese immigrants from the Mediterranean area (42.9% of the fauna in the Burdigalian and 60.9% in the Middle Miocene). Endemism is low during Miocene, with endemic species not exceeding 25% of total Portuguese echinoid fauna".

Following its migration toward the North, *Amphiope* reached the French coast until the Bay of Biscay, where it has been reported in the Serravallian

deposits; its migration toward the North seems to stop in the great inland sea that covered the Touraine, where different sites related to Middle-Late Miocene (Serravallian-Tortonian) are reported. However, after the closure of the pre-Pyrenean Corridor, in Aquitaine an endemic fauna probably developed independently and directly from the original Aquitanian *Amphiope ovalifora* Fallot, 1903.

In conclusion, along the Italian peninsula, *Amphiope* was found in the Middle Miocene of Tuscany (Giannini, 1957) and Campania (Barbera & Tavernier, 1989); in the first case it is unclear whether the migration is linked to the movement of microplates along the Mediterranean, or if it occurred directly from North along the peninsula coasts. However, the presence of *Amphiope* in the Middle Miocene of Campania and in the Tortonian of Sicily (Garilli et al., 2010), can be connected with the approach of the Calabrian microplate (Fig. 14). During the Burdigalian this microplate moved to the East bringing the original fauna, as stated by the findings in the Tortonian deposits of Cessaniti near Vibo Valentia (Cottreau, 1914).

CLIMATE CHANGE, LIMIT OF THE DIFFUSION

To understand the diffusion of scutelliforms living nearshore, we need to consider the trend of climate change from the Cretaceous on to the Miocene, and how it conditioned the life of organisms inhabiting the continents and oceans of the northern hemisphere and Southern Africa. As summarized by Harzhauser et al. (2007), the warm climate of the Cretaceous continued into the Early Palaeogene, with a distinct optimum that characterized the Paleocene-Eocene transition. Starting in the Late Eocene, a gradual decrease in temperature culminated around the Eocene-Oligocene boundary, leading to the formation of the first Antarctic ice cap. From the late Oligocene times, the trend of increasing temperature continued intermittently until the Middle Miocene, when it reached its maximum (Climate Optimum).

Around 14.2 Ma began the transition of the Middle Miocene climate, characterized by the cooling of surface waters and the expansion of the East-Antarctic ice cap (Shevenell et al., 2004), and during this time the extinction of *Parascutella*

and *Amphiope*, began, thus stopping their diffusion to the south. Only for "*Echinodiscus*" migration will continue in the Indian Ocean and along the coast of South Eastern Europe to settle in the current positions.

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The echinoid genus *Amphiope* L. Agassiz, 1840 (Echinoidea Astriclypeidae) in the Oligo-Miocene of Sardinia (Italy)

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ABSTRACT The records of the genus *Amphiope* Agassiz, 1840 (Astriclypeidae) from Sardinia are revised on the basis of 110 specimens, collected from 15 localities of Oligo-Miocene age. Since the morphological characters stated in the literature to distinguish the species of *Amphiope* described in this region cannot provide a clear separation between them, analyses of the plate patterns and of the internal test structure are introduced as taxonomic tools useful for species-level taxonomy in this genus. Five different species of *Amphiope* are identified. Three of the six species erected on the basis of fossil material from Sardinia are confirmed as valid: *Amphiope lovisatoi* Cotteau, 1895, *A. montezemoloi* Lovisato, 1911 and *A. nuragica* (Comaschi Caria, 1955). Two additional species are left in open nomenclature. The morphological descriptions and the stratigraphical distributions are updated and improved.

INTRODUCTION

The genus *Amphiope* L. Agassiz, 1840 (Echinoidea Astriclypeidae) is known from the Oligocene and Miocene of Central and Southern Europe, Northern Africa, Angola, Middle East, India (Smith & Kroh, 2011).

It is well represented also in the Oligo-Miocene of Sardinia (Fig. 1) since ten species of *Amphiope* were recorded in the literature (Table 1), six of which were erected as new taxa on the basis of Oligo-Miocene fossils from this region: *A. lovisatoi* Cotteau, 1895, *A. dessii* Lovisato in Cotteau, 1895, *A. montezemoloi* Lovisato, 1911, *A. pallavicinoi* Lovisato, 1914, *A. calvii* Lovisato, 1914 and *A. nuragica* (Comaschi Caria, 1955). *A. montezemoloi* was

subsequently placed into synonymy with *A. bioculata* (des Moulins, 1837), the type-species of the genus, by Comaschi Caria (1955), Philippe (1998) and Kroh (2005); the last author considered also *A. lovisatoi* as synonymous with *A. bioculata*. Since the type-specimens belonging to Lovisato's collection, at that time housed at the "Regio Museo Mineralogico e Geologico di Cagliari", were lost in 1943 (Comaschi Caria, 1955), this work is based mainly on new material collected from the respective type-localities and on the holotype of *A. nuragica*, still available to study at the "Dipartimento di Scienze Chimiche e Geologiche, Università di Cagliari".

The genus *Amphiope* accounts for more than 40 species, most of which are nominal species in need of revision, due to high intraspecific variation and

Figure 1. Regions of Italy in which *Amphiope* has been recorded in the literature (dark grey). Enlarged area (Sardinia): finding localities examined in this study (black circlets), or recorded in the literature (grey squares). Province of Sassari: 1 = Porto Torres; 2 = La Crucca; 3 = Bancali; 4 = San Giorgio; 5 = Sedini; 6 = Monte Oria Pizzinnu; 7 = Billiu and Monte Sa Loca, near Chiaramonti; 8 = San Matteo, near Ploaghe; 9 = Ardara; 10 = Bessude; 11 = Bonnanaro; 12 = Monte Zarau, near Torralba; 13 = Bonorva. Province of Oristano: 14 = Nuraghe Caiu, near Villa Sant'Antonio; 15 = Laconi; 16 = Bruncu Muntravigu and Tanca Sierra, near Senis; 17 = Duidduru and Genoni (Nuoro); 18 = Monte Is Casteddus, near Isili; 21 = Santadi and Sa Lisporra, at Capo Frasca. Province of Cagliari: 19 = Cuccuru Tuvullao; 20 = Strintu 'e Melonis and Nurri; 23 = Monte S. Michele; 24 = Capo S. Elia and Bonaria. Medio Campidano province: 22 = Monte Arcuentu.

poor species definition (Smith & Kroh, 2011). The complex taxonomy of this genus has been traditionally based on the external morphological features, mainly test outline, size and shape of lunules and petals. Structural characters, largely used in the taxonomy of other clypeastroids (Durham, 1955; Lohavanijaya, 1965; Mooi, 1989; Kroh, 2005; Jansen & Mooi, 2011), were almost overlooked in earlier studies dealing with *Amphiope* and, although several species of *Amphiope* have been described in the literature, important features for species-level taxonomy, such as oral plating, were poorly illustrated or omitted completely.

During a preliminary investigation we attempted to find out whether the specimens from Sardinia might be attributed to already known species, but a particular difficulty was found in the use of the external characters alone, because comparison with taxa whose structural characters are unknown remained uncertain. This paper presents the results of further studies based on a large and well preserved fossil sample, to bring light into the problem of classification of *Amphiope*. The main purpose is a modern revision of Sardinian occurrences of *Amphiope*, using morphological and morphometric analyses, with emphasis on the plate patterns and the internal test support system.

Geological setting

The geology and palaeoecology of the Sardinian *Amphiope*-bearing localities cited in this study were described by Stara et al. (2012) and Mancosu & Nebelsick (2013). In the following a brief summary is given of the type localities of the three species revised from this region.

Central Sardinia (Marmilla). Three main marine sedimentary cycles have been recognized in the Sardinian Basin, from late Oligocene to early Messinian (Assorgia et al., 1997; Funedda et al., 2000; Carmignani et al., 2001). The *Amphiope*-bearing deposits in Central Sardinia belong to the first cycle, extending from the late Oligocene to the late Burdigalian. The Cenozoic sequence starts with the late Oligocene-early Aquitanian Ussana Formation (Pecorini & Cherchi, 1969), consisting mainly of sediments of continental origin. The Ussana Formation is partly heteropic with and is followed by the Nurallao formation, late Chattian-early Burdigalian (Serrano et al., 1997), which consists of the "Conglomerato di Duidduru" member, made of coarse clastics from transitional (deltaic) environments (Sowerbutts & Underhill, 1998) and the littoral marine deposits of the Arenarie di Serralonga member, late Oligocene-early Aquitanian (Assorgia et al., 1997; Barca et al., 2005), which yielded the *Amphiope* specimens examined from this area. The Nurallao Formation is partially heteropic with and followed by the Calcari di Villagreca, dated to the late Oligocene-early Burdigalian, and by the Marmilla Formation, dated to the Aquitanian (Cherchi et al., 2008). The material studied from this area was collected from eight localities: Villa Sant'Antonio, Bruncu Muntravigu, Tanca Sierra, Duidduru,

Recorded species	Cited by	Locality (Province)
A. bioculata (des Moulins, 1837)	Lambert (1907)	Capo S.Elia (Cagliari)
	Comaschi Caria (1955, 1972)	Cuccuru Tuvullao (Cagliari)
	Barca et al. (2000)	Thiesi (Sassari)
	Spano et al. (2002)	Capo Frasca (Oristano)
A. hollandei Cotteau, 1877	Cotteau (1895)	Castelsardo (Sassari), Capo S. Elia and Monte S. Michele (Cagliari), Santadi (Oristano)
	Lovisato (1911, 1914)	Capo Frasca (Oristano), Nurri (Nuoro), Torralba (Sassari)
A. lovisatoi Cotteau, 1895 *	Cotteau (1895)	Billiu* near Chiaramonti (Sassari)
	Comaschi Caria (1955, 1972)	Cuccuru Tuvullao (Cagliari)
A. dessii Cotteau, 1895 *	Cotteau (1895)	Nurri* (Nuoro)
	Lovisato (1914)	Bessude (Sassari)
	Comaschi Caria (1955, 1972)	Cuccuru Tuvullao (Cagliari)
A. montezemoloi Lovisato, 1911 *	Lovisato (1911)	San Giorgio* near Sassari
A. deydieri Lambert, 1912	Comaschi Caria (1955, 1972)	Cuccuru Tuvullao (Cagliari)
A. transversivora Lambert, 1912	Comaschi Caria (1955, 1972)	Cuccuru Tuvullao (Cagliari)
A. calvii Lovisato, 1914 *	Lovisato (1914)	San Matteo* near Ploaghe (Sassari)
A. pallavicinoi Lovisato, 1914 *	Lovisato (1914)	Monte Zarau* near Torralba (Sassari)
	Comaschi Caria (1955, 1972)	Cuccuru Tuvullao (Cagliari)
Amphiope sp.	Lovisato (1914)	Nulvi and Bonorva (Sassari); Monte Arcuentu (Oristano), Sant'Antonio Ruinas (actually Villa S. Antonio), Laconi, Genoni, Capo S. Elia and Monte S. Michele (Cagliari).
A. nuragica (Comaschi Caria, 1955) *	Comaschi Caria (1955, 1972)	Cuccuru Tuvullao* (Cagliari)
Amphiope sp.	Stara et al., 2012	Cuccuru Tuvullao, Monte is Casteddus and Isili (Cagliari); Nuraghe Caiu, Bruncu Montravigu and Tanca Sierra (Oristano); Duidduru (Nuoro); Bancali; La Crucca; Porto Torres; Ardara; Chiaramonti and Bonnanaro (Sassari)

Table 1. Records of *Amphiope* from Sardinia reported in the literature. An asterisk marks the species firstly described on the basis of material collected from this region.

Genoni, Isili, Cuccuru Tuvullao and Capo Frasca (see Fig. 1).

- Cuccuru Tuvullao (n. 19 in Fig. 1). The type-locality of *A. nuragica* (Comaschi Caria, 1955) is located 1.5 km NE of Nuragus (Cagliari). *Amphiope* occur in high numbers in a medium to coarse-grained volcanoclastic sandstone (herein named C. Tuvullao I), 2-2.5 m thick, corresponding to the "Facies B" of Mancosu & Nebelsick, 2013; Fig. 2). *Amphiope* is the most abundant taxon, followed by *Parascutella* sp., reworked balanids and bivalves. Seven species of *Amphiope* were cited by Comaschi Caria (1955) in this layer, including *A. nuragica*. The echinoids are denuded, commonly fragmented in the shape of pie-slices. Loosely packed or dispersed specimens are both in life position and up-side down, their long axes being more or less parallel to the stratal surfaces. This sand dollar deposit is assigned to a shoreface environment and represents a multiple in situ reworking accumulation (Mancosu & Nebelsick, 2013).

Fragments and rare complete specimens of *Amphiope* occur also at the base of the overlying richly fossiliferous fine mudstone (herein named C. Tuvullao II), corresponding to the "Facies C" of Mancosu & Nebelsick (2013); Fig. 2). The fossil content is dominated by gastropods, belonging to the genus *Turritella* Lamarck, 1799, and by the bivalve *Panopea* Ménard, 1807.

Northern Sardinia. Seven *Amphiope*-bearing localities were sampled in the Sassari province: Porto

Torres, La Crucca, Bancali, San Giorgio, Chiaramonti, Ardara and Bonnanaro. These deposits belong to the second Cenozoic sedimentary cycle, late Burdigalian-early Langhian (Mancosu & Nebelsick, 2013). At the base, the lacustrine and fluviodeltaic sediments of the Oppia Nuova formation (Funedda et al., 2000) are overlain by the Calcari di Mores Formation, consisting of bioclastic limestones and poorly cemented sands of shallow water origin (Mazzei & Oggiano, 1990; Funedda et al., 2000). The Calcari di Mores Formation is followed by the Marne di Borutta Formation, which represents a deeper shelf facies.

- Chiaramonti (n. 7 in Fig. 1). Billiu, the type-locality of *A. lovisatoi*, rests along the main road from Ploaghe, close to Chiaramonti. The specimens examined in this paper were collected from the section studied by Stara et al. (2012) cropping out at Monte Sa Loca, less than 1 km far from Billiu: it is 9 m thick and extends laterally for some 40 m. The main *Amphiope*-bearing layer corresponds to the "Facies C" of Mancosu & Nebelsick (2013; Fig. 4), dated to the lower part (late Burdigalian) of the Calcari di Mores Formation, and represents the lateral extension of the strato-type of Billiu. It consists of very coarse, poorly sorted, massive sandstone, about 1 m-thick, with carbonate cement, which, though discontinuous, can be traced over the entire length of the outcrop. The dense accumulation of well-preserved echinoids of Facies C is considered to represent an autochthonous assemblage in a shoreface environment (Mancosu & Nebelsick, 2013). *Amphiope* prevails by far, followed in abundance by *Agassizia* Yoshiyasu, 1987, *Parascutella* Durham, 1953, *Echinolampas* Gray, 1825 and small bivalves, and is represented almost exclusively by complete tests (80%) with subordinate fragmented tests.

- San Giorgio (n. 4 in Fig. 1). The type locality of *A. montezemoloi* was never cited again since its original description. It has been traced by one of the authors (P.S.) following the indication of Lovisato (1911; 1914), along the Sassari-Alghero railroad, 1.5 km far from the abandoned rail-station of San Giorgio towards Olmedo. The *Amphiope*-bearing outcrop consists of a coarse-grained sand-stone and extends for a few square meters, only. *Amphiope* is mainly represented by fragmented specimens in chaotic position.

MATERIAL AND METHODS

The studied material consists of 110 specimens, preserved as whole coronas deprived of the spines, and several fragmented individuals, from 15 Miocene Sardinian localities (Fig. 1). Most of them are
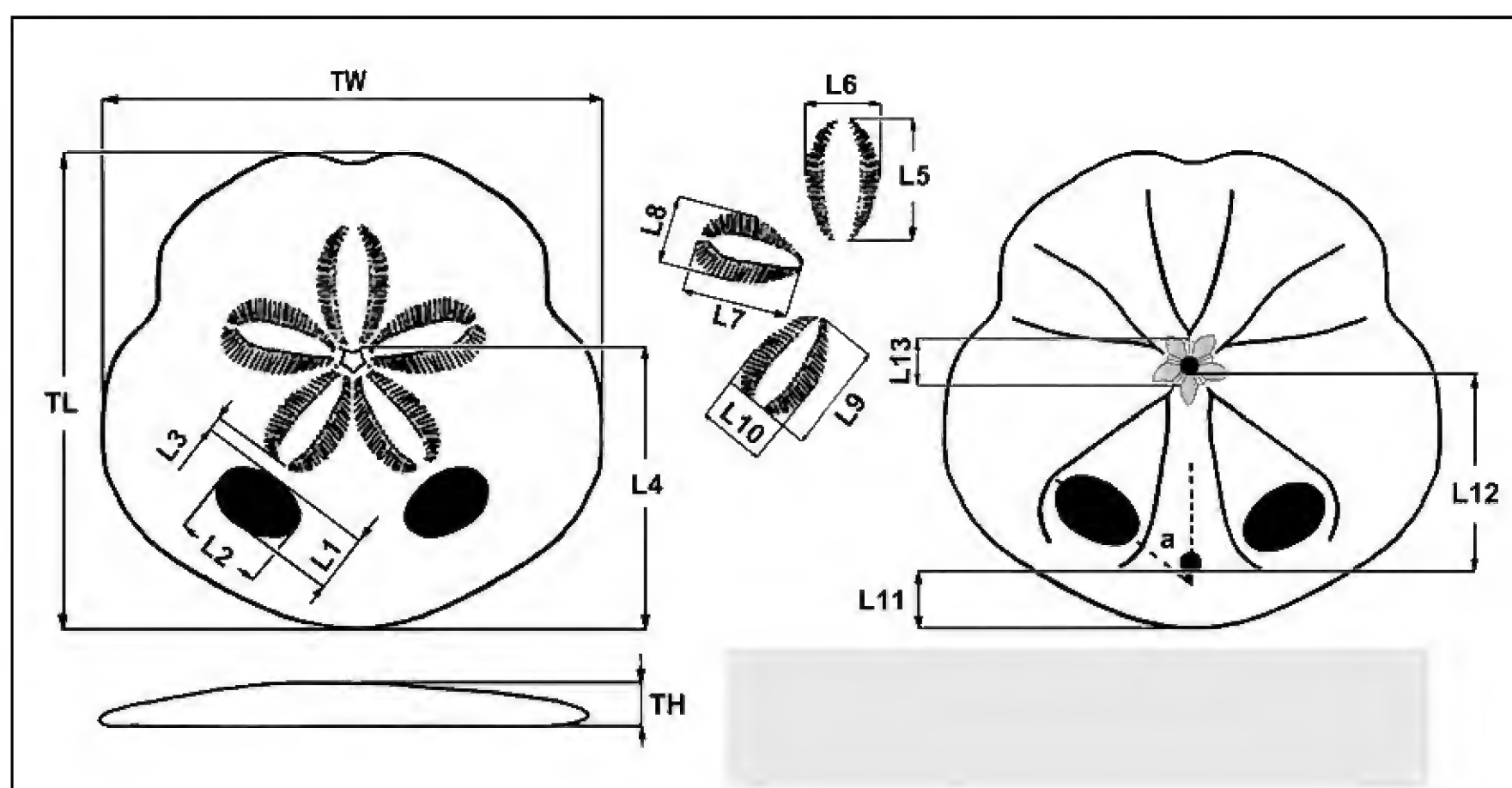

Figure 2. *Amphiope*: scheme of the biometric parameters measured in the studied specimens.

housed at the Museo di Storia Naturale "Aquilegia" of Cagliari (MAC code): 95 specimens were collected by one of the authors (P.S.), 12 specimens were donated by private collectors. Three additional specimens have been examined in the Dipartimento di Scienze Chimiche e Geologiche, Università di Cagliari (UNICA); they include the holotype of *A. nuragica* (code 9CC.8-10504) and two specimens classified as "*A. calvii*" (code 3CC) and "*A. dessii*" (code 6CC-10503) by Comaschi Caria (1955; pl. 1 and pl. 7, respectively).The other specimens from Cuccuru Tuvullao described by Comaschi Caria (1955) have not been traced at the UNICA. The measurements of ten lost specimens, reported by Lovisato (1911; 1914) and Comaschi Caria (1955), were used in the statistical biometrical analyses; since some data were lacking, they were taken from the figures given by Comaschi Caria (1955: pl. 2, figs. 1, 2, pl. 3, figs. 1, 2, pl. 4, figs. 1, 2, pl. 5, figs. 1, 2, pl. 6, figs. 1, 2, pl. 8, figs. 1, 2, pl. 9, figs. 1, 2, pl. 13, fig. 1; 1972: pl. 44. figs. 3-4).

According to Lovisato (1911; 1914) the specimens he provided for study to other echinologists, including the type series used by Cotteau (1895) to erect *A. lovisatoi* and *A. dessii*, returned back to his collection at that time stored in the "Regio Museo Mineralogico e Geologico di Cagliari". All those specimens, as well as the type material of the other species based on fossils from Sardinia, with the exception of *A. nuragica*, were lost in 1943 during the 2nd World War (fide Comaschi Caria, 1955).

The internal structure was studied by sectioning the test, and by X-ray; 5 specimens from Bancali, 3 from C. Tuvullao, 2 from Bonnanaro and 2 from Chiaramonti were used for this purpose.

Morphological abbreviations (Fig. 2) -α = angle between the axes of the two posterior petals; TL = test lenght; TW = test width; TH = test height; L1-L2 = lunule length and width, respectively; L3 = distance posterior petal tip from the corresponding lunule; L4 = distance apical system-posterior margin; L5-L6 = length and width of the frontal petal, respectively; L7-L8 = length and width of the anterior paired petal, respectively; L9-L10 = length and width of the posterior petal, respectively; L11 = distance posterior border of periproct and of the test; L12 = distance between the posterior border of the peristome and of the periproct; L13 = antero-posterior diameter of the basicoronal circlet. Measurements of L1 to L10 were taken from the left side of the test, where possible. Systematic palaeontology follows Kroh & Smith (2010).

Broken edges were indicated by dotted lines in drawings, heavier lines indicate unbroken ambitus. Plates were numbered according to Lovén's system (CIT; compare Plate 1 Fig. 3b), interambulacral plates were shaded in grey.

Geographic coordinates on the World Geodetic System of 1984, WGS84.

Biometric analyses were carried out and data analyzed using the software PAST -version 1.97 (2010) (Hammer & Harper, 2010; Hammer et al., 2001), to help interpret the samples collected from eight Sardinian localities. The original values of the metric parameters were divided by TL to exclude the effect of size, as suggested by Durham (1955), Lohavanijaya (1965) and Pereira (2010). Principal component analysis (PCA) is based on 71 specimens [8 from Bancali, 4 from Bonnanaro, 34 from Chiaramonti, and 25 from C.Tuvullao (22 from layer I and 3 from layer II)]. The analysis utilizes 11 variables: TW/TL, TH/TL, L1/TL, L2/TL, L3/TL, L4/TL, L5/TL, L6/TL, L9/TL and L10/TL. Univariate and bivariate analyses were based on a data set taken from 79 specimens: 9 from Bancali, 38 from Chiaramonti and 28 from C.Tuvullao (25 from layer I and 3 from layer II) and 4 from Bonnanaro-San Giorgio.

RESULTS: MORPHOLOGICAL FEATURES OF *AMPHIOPE* FROM SARDINIA

LUNULES. Though a large variability is present in the outline, lunules are commonly large-sized and subcircular (Plate 4 Fig. 14c) to broad elliptical (Plate 4 Fig. 14b) at Bancali, Ardara, Villa S. Antonio, Bonnanaro and San Giorgio. Similar shaped, but smaller, lunules occur at Porto Torres and La Crucca, whereas they are mainly broad elliptical (Plate 1 Figs. 1, 2) at Chiaramonti and narrow-elliptical at C. Tuvullao (Plate 2 Figs. 13b–d). Specimens from different localities bearing similar-shaped lunules often have different external test characters and/or internal structure, so that test and lunules features are not univocally linked. Lunules may be different even in a single specimen (e.g. Plate 1 Fig. 3a).

PLATE STRUCTURE. A number of constant structural features are recognized in the studied material:

- Interambulacral columns are always disjunct adorally, plate 2b and sometime both plates 2a and 2b being separated from the basicoronals by enlarged first ambulacral post-basicoronal plates.

- Oral interambulacra 1, 4, 5 are meridoplacous, whereas interambulacra 2 and 3 may be either amphiplacous or, more frequently, meridoplacous.

- The first post-basicoronal plates are the longest of the series, both in ambulacral and interambulacral columns. In interambulacrum 5, the plate 2b is more elongate than 2a.

- There always is a higher number of plates aborally than adorally in each column.

- There is almost the same number of plates in each column of interambulacra 1, 4, 5 and ambulacra I and V: 14–15, seldom 16, plates in the specimens of Bancali and Chiaramonti, whereas they are more numerous (16-20) at C. Tuvullao. The same condition occurs in interambulacra 2 and 3, and in ambulacra II, III and IV: 14–16 plates in each column at C. Tuvullao I, 12-14 at Bancali and only 10–13 at Chiaramonti.

- Lunules walls have vertical sutures (Pl. 4 Fig. 8) corresponding to the *Echinodiscus*-type ("cross linked" sutures, sensu Mooi, 1989). Adorally, lunules begin to open in correspondence of the second pair of post-basicoronal plates, whereas 1–2 couples of plates separate lunules from the petal tips, aborally. Plates encircling lunules are more numerous on the aboral side (6–9) than adorally (3–5).

The composition of the oral interambulacrum 5 is characteristic (Table 2): at C. Tuvullao I the normal condition is 3 (33% of cases; Plate 2 Fig. 1b) to 4 plates (67%) in column 5b, whereas in all the other samples there are only 2 post-basicoronal plates in column 5a and 3 in 5b (Plate. 4 Figs. 11, 12).

Also the position of the periproct is highly characteristic (Table 2): the specimens of C. Tuvullao II have the periproct far from the posterior test margin and bounded by the first pair of post-basicoronal plates 2a/2b (Plate 3 Figs. 9b, 10b). At Bancali, Bonnanaro and San Giorgio the periproct is invariably associated with plates 2a/3b (Plate 3 Figs. 2a, b; Plate 4 Figs. 11, 12), usually positioned halfway along the suture. This is the most frequent condition also at Chiaramonti, but at this locality the periproct opens more distally, near the outer edge of plates 2a/3b towards plate 3a (Plate 1 Fig. 3b), or just at the conjunction point 2a/3b/3a (9 cases of 27; Plate 1 Fig 4b), sometimes even between 3a/3b (3 cases). At C. Tuvullao I the periproct is commonly found (21 cases of 41 = 51%) at the conjunction point 2a/3a/3b (Plate 2 Figs. 1b, 2b) or more distally (22%; Plate 2 Fig. 3).

The interambulacral basicoronal circlet is very variable in shape and size, even at the same locality. The ambulacral circlet is more homogeneous: the mean value of L13 is 11.3% TL at Bancali and 10.8% at C. Tuvullao I; it is smaller at Chiaramonti, Bonnanaro and San Giorgio.

Locality	Position of the periproct								Plates present in the interambulacrum 5 adorally			
	2b/2a	2b/2a/3b	2a/3b	2a/3b/3a	3b/3a	3a/4b	3b/3a/4b	3b/4a/4b	3a/4b	4a/4b	4a/5b	5a/5b
Ardara	-	-	2	-	-	-	-	-	1	-	-	-
Bancali	-	-	9	-	-	-	-	-	7	2	-	-
Bonnanaro	-	-	3	1	-	-	-	-	2	1	-	-
Chiaramonti	-	-	14	9	3	1	-	-	19	5	-	-
C.Tuvullao (I)	-	-	11	21	5	1	2	1	-	12	21	3
C.Tuvullao (II)	2	1	-	-	-	-	-	-	2	1	-	-
La Crucca	-	-	3	-	-	-	-	-	-	-	-	-
Porto Torres	-	-	1	-	-	-	-	-	-	1	-	-
Senis	-	-	1	-	-	-	-	-	-	-	-	-

Table 2. Plates present in the interambulacrum 5 adorally and position of the periproct in the examined samples of *Amphiope* from Sardinia.

INTERNAL TEST STRUCTURE. It consists of a well developed peripheral ballast system surrounding a central cavity with domed ceiling. The extension of the central cavity roughly corresponds to the petaloid area; adorally, it does not extend beyond the distal border of the first pair of post-basicoronal ambulacral plates, in all samples. In the specimens of Chiaramonti the central cavity has an almost flat floor and is bordered by thin transversely elongate straight walls delimiting a sub-pentagonal area (Plate 1 Fig. 8). At Bancali, Bonnanaro and San Giorgio the first pillars of the radiating interambulacral buttresses (Plate 3 Fig. 5a, Plate 4 Fig. 7) are stronger and get closer to the centre, thus forming an almost "starring" outline (Plate 4 Fig. 15). At C. Tuvullao I the floor of the interambulacra begin to thicken close to the peristome and gradually rise towards the first pillars of the radial supports (Plate 2 Fig. 11); the central cavity has a rough sub-circular outline, with floor and ceiling thicker than in the specimens from Bancali and much thicker than those from Chiaramonti, Bonnanaro and San Giorgio (Plate 3 Fig. 7). The convexity present on the external surface of the petals contributes to strengthen the ceiling. In the specimens from C. Tuvullao I the whole petal surface is convex whereas only the interporiferous areas are convex at the other localities.

The lantern muscle attachment structures always consist of five fused interradial pegs (Plate 1 Fig. 8). The peripheral ballast system is made of a series of sub-cylindrical pillars and walls extending from the ceiling to the floor and crossed by cavities. Towards the ambitus it becomes very dense, almost massive, and crossed by micro-canals, in all the examined samples.

On the whole, the support system is strongly developed in the specimens of C. Tuvullao I and II, whereas it is lighter and more complex at Bancali and much lighter at Bonnanaro, San Giorgio and Chiaramonti.

RESULTS OF BIOMETRIC ANALYSES

The PCA analysis resulted in three components accounting for more than 70% of the total variance in the data set. The first (PC1) explains 35.5% of the variance; the ratios TW/TL and TH/TL enter the heaviest loading into PC1. The second compo-

nent (PC2) is mainly controlled by L4/TL, the third (PC3) by the lunule dimension variables. On the whole, the PCA scatterplot (Fig. 4) shows large overlaps in the distributions of specimens from the different localities in multivariate space, delimited by convex hulls. Only the samples from C. Tuvullao I and Bonnanaro are clearly separate from that of C. Tuvullao II. According to the PCA analysis results, the specimens from C. Tuvullao I and II present higher test and lunules with lower values of L1 and higher values of L2.

Descriptive statistics resulting from the univariate analysis are reported in Table 3. The bivariate plots confirm that the specimens from C. Tuvullao II have much higher test (Fig. 3), the length of the frontal ambulacrum and the distance of the periproct from the posterior test margin have more elevate values than those from layer I, the apical disc is more centrally located. The sample from C. Tuvullao I has higher tests and more transversely elongated lunules than those from the other localities (Fig. 5), with the exception of C. Tuvullao II. The specimens from Chiaramonti and Bonnanaro-San Giorgio have a very low test (Fig. 3). At Chiaramonti the frontal petal has almost the same length of the posterior petals (mean L9 = 95.1% L5), whereas it is slightly longer at C. Tuvullao I, Bancali, Bonnanaro (mean of L9 ranging from 86.6 to 88.8% L5), and much longer at C. Tuvullao II (mean L9 = 79.1% L5, only).

On the whole, the statistical analyses indicate the presence of five different morphotaxa in the studied material, corresponding to the samples from C. Tuvullao I, C. Tuvullao II, Bonnanaro-San Giorgio, Chiaramonti, Bancali.

DISCUSSION

The material under study indicates a large variability of the morphological characters stated to separate the species of *Amphiope* recorded from Sardinia, mainly consisting of the external test features: test outline, size and shape of lunules and petals (Cotteau, 1877, 1895; Lovisato, 1911, 1914; Cottreau, 1914; Comaschi Caria, 1955, 1972; Philippe, 1998).

Using these "diagnostic" characters, Comaschi Caria (1955) recognized seven species at C. Tuvullao I.
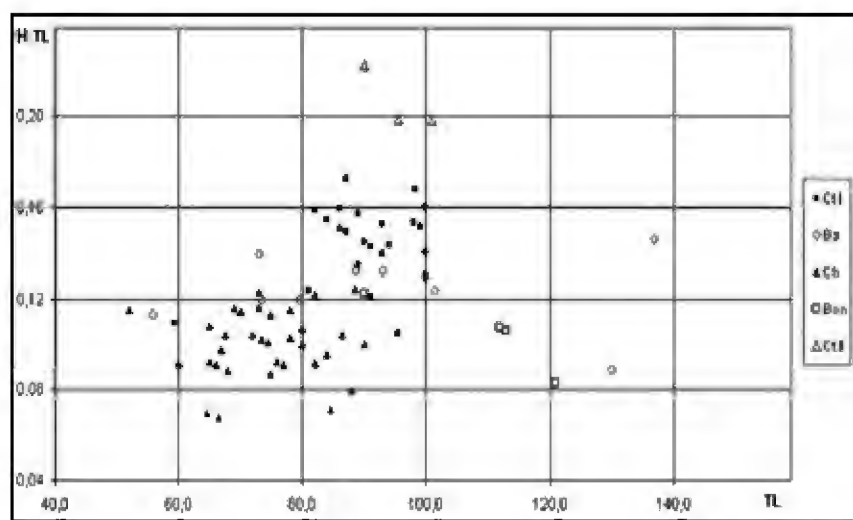
Figure 3. *Amphiope* from five Sardinian localities: bivariate plot of test height (values of H divided by TL) against test length (TL, in mm). Legend: Ba = Bancali; Bon = Bonnanaro; Ch = Chiaramonti; Ct I and Ct II = Cuccuru Tuvullao, layer I and layer II, respectively.
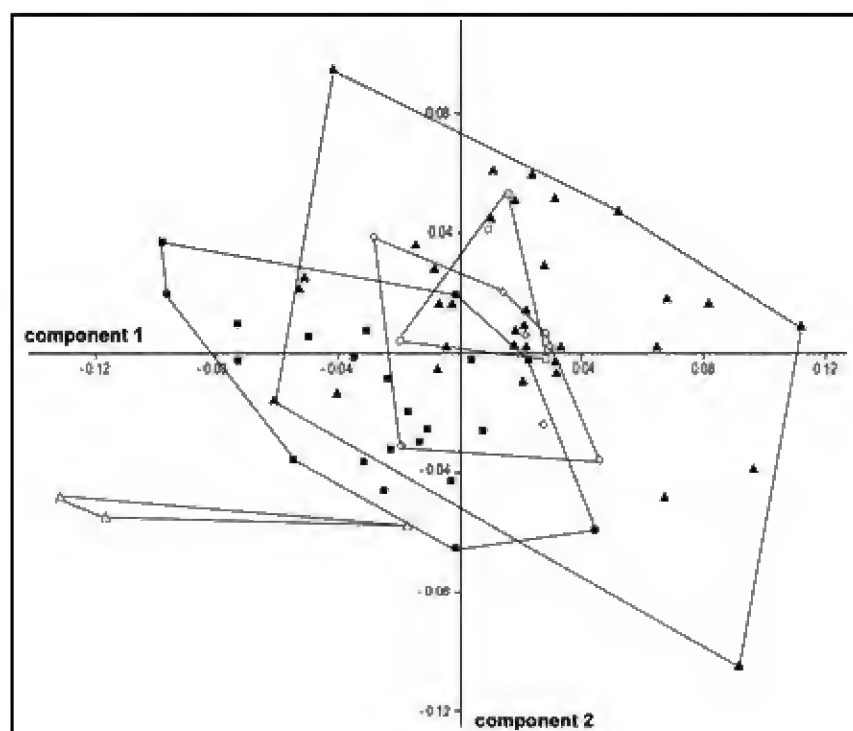

Figure 4. Scatter diagram of PCA analysis based on specimens of *Amphiope* from five Sardinian localities. The legend is reported in figure 3.
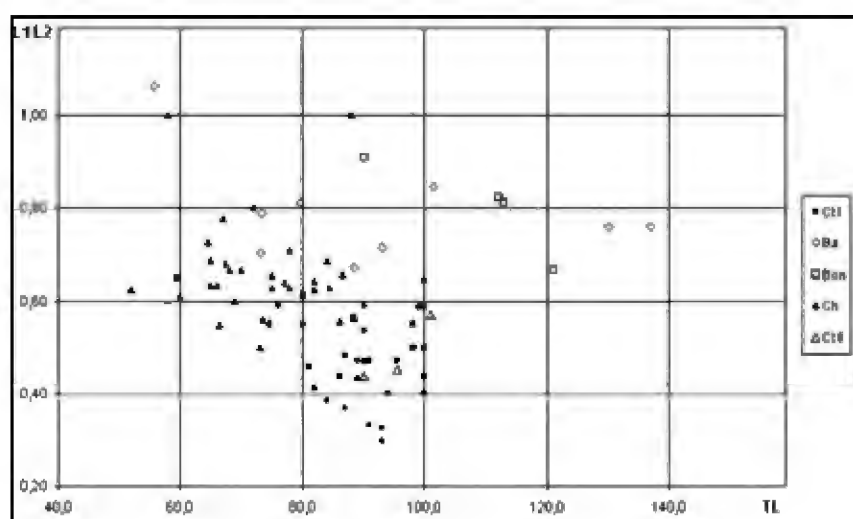

Figure 5. *Amphiope* from five Sardinian localities: bivariate plot of L1/L2 ratio against the test length (TL, in mm). The legend is reported in figure 3.

However, intermediate cases are present in the sample studied from this locality. On the other hand, basing on the recent interpretation of *A. bioculata* by Philippe (1998) as a taxon with large morphological variability and stratigraphical distribution, the examined material from Sardinia should be attributed to a single species. The specimens bearing the "diagnostic" characters of *A. lovisatoi*, *A. pallavicinoi* and *A. calvii* could be included in the variability range of "population B" of *A. bioculata* described by Philippe (1998; fig. 15 b, e; pl. 16, fig. 6). The same case occurs with the *A. transversivora-A. deydieri-A. hollandei* group, which is close to "population A" (Philippe 1998; fig. 14 d-f; pl. 16, fig. 4), and with *A. montezemoloi*, apparently corresponding to "population D" (Philippe 1998; fig. 17d, pl. 16, fig. 5).

The results of the biometric analyses clearly show a number of significant differences and point to the occurrence of at least five different morphotaxa in the studied sample.

To tackle the uncertainty, the analysis of the structural features is introduced in the taxonomy of *Amphiope*. The plate patterns and the inner test structure have already been utilized in the classification of other clypeasteroid genera (Durham, 1955; Lohavanijaya, 1965; Mooi, 1989; Jansen & Mooi, 2011). The arrangement of the plates in echinoids is fixed early in ontogeny and the basic pattern does not change during further growth in most forms, especially in scutelliform echinoids in which the plates forming the sharp ambitus are of special form and prevent plate translocation from the aboral to the oral side during later growth (Kroh, pers. comm., 2012). The taxonomic potential of the plate structure has been recently tested by Stara & Sanciu (2014) in *Echinodiscus* Leske, 1778, a genus closely related to *Amphiope*. The results indicate that the position of the periproct, the shape and the number of plates in the oral interambulacrum 5 clearly separate *E. auritus* Leske, 1778 from the other extant species of *Echinodiscus*. These features are expected to provide a taxonomic potential also in *Amphiope*. Indeed, structural features are well preserved in the studied material from Sardinia and show a low variability; additionally, the structural differences identified between the Sardinian samples match with the diversities indicated by the morphometric analyses.

Basing on the external test morphology, the study of the structural characters and the statistic biometric analyses, the specimens from Chiaramonti (Pl. 1) are assigned to *A. lovisatoi* since they were collected from the type locality of this species and they are consistent with the original description and illustration given by Cotteau (1895) and Lovisato (1914): test very low with sharp margin and rather broad, transversely elongated elliptical lunules. The sample from this locality is clearly separated from the others by the combination of structural characters: only two post-basicoronal plates present in the oral interambulacral column 5a, periproct located in the posterior part of the suture between plates 2a/3b, internal structure very light with thin shell and subpentagonal central cavity.

Well-preserved material recently collected from San Giorgio, the type-locality of *A. montezemoloi* Lovisato, 1911, and Bonnanaro, corresponds to the original description of this species: large-sized and anteriorly constricted test, with broad subcircular lunules (Plate 3 Figs. 3a, b). *A. montezemoloi* differs statistically from *A. lovisatoi* by a much larger test. Additionally, the specimens from Chiaramonti have smaller and more elongate lunules, the frontal petal almost as long as the others, the internal structure is lighter and the central cavity is subpentagonal not starring as in *A. montezemoloi*.

The holotype of *A. nuragica* (Plate 2 Figs. 1a, b) has four post-basicoronal plates in the oral interambulacral column 5b, three in column 5a, and the periproct is located at the conjunction of plates 2a/3a/3b. Comparison with the specimens collected from the type-layer (C. Tuvullao I) with the holotype is entirely consistent. No significant statistical differences were observed between the specimens with the periproct close to the conjunction point 2a, 3a, 3b and those with the periproct more posteriorly located. The characteristic and strong internal test structure is present in all the specimens from this bed. Thus, the whole sample from C. Tuvullao I is assigned to *A. nuragica* (Comaschi Caria, 1955). The combination of the peculiar structural features distinguishes *A. nuragica* from all the other Sardinian examined samples.

The specimens from C. Tuvullao II stand apart from all the others from Sardinia by much higher test, apical system more centrally located, frontal petal much longer than the posteriors and the periproct

bounded by the first pair of post-basicoronal plates. Due to the scarcity of the available material these specimens are assigned to *Amphiope* sp. 1, and left in open nomenclature.

The specimens of Bancali (Plate 4 Figs. 1–3), though rather similar to those from San Giorgio-Bonnanaro, differ statistically from *A. montezemoloi* by more elevate test, larger ambulacral basicoronal circlet and smaller lunules, and by a stronger internal structure. The same differences separate them from *A. lovisatoi*; additionally, the specimens from Chiaramonti are smaller and the periproct, though bounded by plates 2a/3b as well as in the sample of Bancali, is closer to the conjunction point 2a/3b/3a. Though the studied sample looks like well differentiated, additional well-preserved material is needed to corroborate the observed differences and to confirm the occurrence of a distinct species. Therefore, the specimens from Bancali are assigned to *Amphiope* sp. 2.

Only scant and poorly preserved material is currently available from the type-localities of *A. dessii* Lovisato in Cotteau, 1895, *A. pallavicinoi* Lovisato, 1914 and *A. calvii* Lovisato, 1914. The oral plating as well as the internal support arrangement of those species were not reported in the original descriptions and cannot be made out from illustrated specimens. Cotteau (1895) attributed a test fragment from Sardinia to *A. hollandei* Cotteau, 1877. Other Miocene specimens from Sardinia were attributed to this species (Lovisato, 1911; 1914). Since all that material was lost (fide Comaschi Caria, 1955) the occurrence of *A. hollandei* in Sardinia is not confirmed.

Most of the *Amphiope* species described in the literature lack primary data on the plating patterns and the internal test structure and are therefore not completely documented in terms of their morphology. This is the case also for the type-species of *Amphiope*: the type locality and stratum of the specimen "*variété 3*" of *Scutella bifora* (see Lamarck, 1816) on which des Moulins (1837) based the diagnosis of *Amphiope bioculata*, are unknown; des Moulins tentatively proposed "*terrain tertiaires*" of Suze la Rousse in the Rhône Basin and Bordeaux (France) as type-localities for that specimen. No well preserved specimens from these localities have been traced in public institutions (Philippe, 1998; pers. comm. B. Martin Garin, March 2013) and the plate patterns could not be taken from figures re-

ported in the literature (Lambert, 1912). Philippe (1998), when studying *Amphiope* from the Rhône Basin, described also specimens from the Serravallian of Suze la Rousse, but he could not describe the plate patterns since they were not preserved.

As a consequence, the structural features of the type-species, as well as of most of the earlier described species of *Amphiope*, are still uncertain/ unknown thus preventing a reliable comparison with the material under study, based on these important characters.

SYSTEMATIC PALAEONTOLOGY

Family ASTRICLYPEIDAE Stefanini, 1912

Genus *Amphiope* L. Agassiz, 1840

TYPE SPECIES. *Scutella bioculata* des Moulins, 1837, by subsequent designation of Lambert (1907, p. 49).

EMENDED DIAGNOSIS. (Partially modified from Smith & Kroh, 2011). Test low with sharp margin. Internal support well developed, consisting of pillars and walls crossed by cavities. Towards ambitus, peripheral ballast system very dense, almost massive and crossed by micro-canals. Apical disc monobasal, sub-central or slightly anterior to centre, with four gonopores. Petals well developed; short (about half radial length of test) and almost closed distally. All five petals similar in length. Ovate lunules or notches present in the posterior ambulacra. Oral side flat or slightly concave. Interambulacra on the oral surface narrower than the ambulacra, even at their widest point. Interambulacra 1, 4 and 5 always meridoplacous adorally, the interambulacral zones being separated by enlarged first post-basicoronal ambulacral plates. Interambulacra 2, 3 may be either amphiplacous or meridoplacous adorally. Basicoronal circlet pentastellate with interambulacral plates forming the points. Peristome small, subcentral or slightly anteriorly located. Periproct circular, small, opening between the first, the second or the third pair of post-basicoronal interambulacral plates. Two to five post-basicoronal plates present in the interambulacrum 5 adorally. Food grooves well developed, bifurcating at the edge of the basicoronal plate; they do not reach the margin.

Posterior pair of food grooves running around the lunules; finer distal branches well developed. Ambulacra a little wider than interambulacra at ambitus. Tuberculation dense, made of very small, perforate and crenulate tubercles, larger on the oral face than aborally.

DISTRIBUTION. Oligocene and Miocene. Central and Southern Europe, North Africa, Middle East, India, Angola (Smith & Kroh, 2011).
Sardinian species included:

• *Amphiope lovisatoi* Cotteau, 1895. Late Burdigalian.
• *Amphiope montezemolo*i Lovisato, 1911. Late Burdigalian-early Langhian.
• *Amphiope nuragica* (Comaschi Caria, 1955). Late Chattian-early Aquitanian.
• *Amphiope* sp. 1. Late Chattian-early Aquitanian.
• *Amphiope* sp. 2. Late Burdigalian-early Langhian.

REMARKS. Both *Amphiope* and *Echinodiscus* Leske, 1778 show two lunules in the posterior ambulacra. *Echinodiscus* differs in having axially elongated, slit-like lunules or notches and posterior petals shorter than the others.

Amphiope lovisatoi Cotteau, 1895
Plate 1 Figs. 1–8; Plate 3 Fig. 7b

1895 *Amphiope Lovisatoi* Cotteau - Cotteau p. 16 pl. 3, fig. 15
1914 *Amphiope Lovisatoi* Cotteau - Lovisato, p. 118, pl. 2, figs. 6a-b
Non 1955 *Amphiope lovisatoi* Cotteau - Comaschi Caria, p. 9, pls. 9, 11, 12.

TYPE-LOCALITY AND HORIZON. Chiaramonti (Sassari). The type-layer described by Lovisato (1914) corresponds to the "Facies C" of Mancosu & Nebelsick (2013; Fig. 4), attributed to the lower part of the Calcari di Mores Formation, dated to the late Burdigalian.

TYPE MATERIAL. Cotteau (1895) did not detail the composition of the type-series provided by Lovisato, nor designated a holotype. All those specimens, as well as the others from Chiaramonti belonging to the Lovisato's collection, were lost in 1943 (fide Comaschi Caria, 1955). They could not be traced by the authors at UNICA. A neotype is proposed herein, to clarify the diagnostic char-

acters of this nominal taxon which cannot be extracted from published descriptions and illustrations of the lost type. Additionally, *A. lovisatoi* has been synonymised with other species of *Amphiope*, and the structure features firstly described in this paper are not visible in the illustration provided by Cotteau (1895) and Comaschi Caria (1955).

Neotype: MAC.PL1706 (Pl. 1 Figs.1a-c and 5a-b), a specimen with both faces well preserved (TL = 73, TW = 77.5, TH = 8.5 mm). It was recovered at Monte Sa Loca (40°44'55.15" N, 8°49'59.20" E), from the main *Amphiope*-bearing bed (Facies C of Mancosu & Nebelsick, 2013), which represents the lateral extension of the type-layer cropping out at Billiu (Stara et al., 2012). Billiu is less than1 km far from Monte Sa Loca, both are located in the suburbs of Chiaramonti. The road-cut of Billiu currently yields only scarce and poorly preserved fossil material, whereas at Sa Loca abundant and well preserved material is available to study.

EXAMINED MATERIAL. The studied sample from the type-locality consists of 61 complete tests (MAC code: PL1301-3, PL1317, PL1413, PL1418-20, PL1422-4, PL1427, PL1429, PL1567-70, PL1572-80, PL1583, PL1585-7, PL1692-99, PL1700-1707, PL1709-1714, PL1715-18, PL1720-23, PL1726) and 7 test fragments.

REVISED DIAGNOSIS. Middle-sized species of *Amphiope* with low test, sharp margin and broad, transversely elongated elliptical lunules. A low number of plates is present in each ambulacral and interambulacral columns, only two post-basicoronal plates occur in the interambulacral column 5a adorally. Periproct bounded by plates 2a/3b, rather close to the posterior test edge. Internal structure very light, with thin shell and sub-pentagonal central cavity.

DESCRIPTION. Middle sized test (mean TL= 76 mm). Outline sub-circular to anteriorly constricted, usually slightly transversely elongated, posteriorly rounded (Plate 1 Fig. 1) or subtruncate (Plate 1 Fig. 3a). Maximal width located subcentrally. Test very low (mean TH = 10.2% TL), with maximum height positioned anteriorly. Marginal indentations well developed in ambulacra II and IV (Plate 1 Figs. 1, 2). Shallow notches may occur also in ambulacra I, III, V and interambulacra 1 and 4. Test edge sharp.

Ambulacra. Frontal and posterior petals similar in length. Poriferous zones depressed; interporiferous zones slightly raised. Interporiferous area larger than the corresponding poriferous one. Lunules transversely elongate and broad elliptical (Plate 1 Figs. 1, 2 and 7d); the shape-variability includes also rare small subcircular (Plate 1 Fig. 7c) and narrow elliptical (Plate 1 Fig. 7a) lunules. Ambulacra slightly depressed adorally, along their central suture. Ambulacral basicoronal circlet small.

Interambulacra. Only 14–16 plates in each column of interambulacra 1, 4, 5 and ambulacra I and V; 10–13 plates in interambulacra 2 and 3, as well as in ambulacra II, III and IV. Adorally, only two, sometimes a small part of the third, post-basicoronal plates in the interambulacral column 5a adorally, three of them in column 5b (Plate 1 Figs. 3b, 4b, 5b).

Periproct. Commonly found in the distal half of the suture 2a/3b (Plate 1 Figs. 3b, 5b).

Internal structure. Reduced, with spaces between elements larger than the calcite elements comprising the buttress system (Plate 1 Fig. 6). Central cavity bordered by five transversely elongate straight walls, delimiting a sub-pentagonal area (Plate 1 Fig. 8). Peripheral ballast system very dense, almost massive towards the ambitus.

Other features as for the genus. See Table 3 for descriptive statistics.

REMARKS. Most of the "diagnostic" features stated for *A. lovisatoi* by Cotteau (1895) and Lovisato (1914) are very variable in the studied sample from Chiaramonti and cannot provide a clear separation from the other Sardinian species. Some specimens do not correspond to "posteriorly rounded test" (e.g. Plate 2 Fig. 3a), or to "deep notches in the margin" (e.g. Plate 2 Fig. 4a), as stated for this species. Only "test middle-sized and depressed" and "sharp margin" are confirmed as valid distinctive characters by this study.

A. lovisatoi was synonymised with *A. bioculata* by Kroh (2005), however, the figured specimen from Austria differs from the Sardinian fossils by much higher test (TH = 20% TL) and by the frontal petal, which is clearly longer than the posterior paired petals (L9/L5 = 0.80 in the Austrian specimen, against 0.95 in the sample of Chiaramonti).

Comaschi Caria (1955) cited this species at C. Tuvullao. However all the specimens from that locality bearing external features similar to those of *A. lovisatoi* had very different plate patterns and

much stronger internal structure, corresponding to that of *A. nuragica*.

OCCURRENCE IN SARDINIA. Chiaramonti, Calcari di Mores Formation, late Burdigalian.

Amphiope montezemoloi Lovisato, 1911
Plate 3 Figs. 1–6, 7a

1911. *Amphiope Montezemoloi* Lovisato - Lovisato, p. 43, pl. 6, figs. 1a, b
1928. *Amphiope montezemoloi* Lovisato - Lambert [36], p. 23, pl. 8, fig. 4
1955. *Echinodiscus* (*Amphiope*) *bioculata* var. *montezemoloi* Comaschi Caria - Comaschi Caria, p. 184, pls. 14, 15
1972. *Amphiope bioculata* des Moulins - Comaschi Caria, p. 42.

TYPE-LOCALITY AND HORIZON. Near the abandoned railway station of San Giorgio (Sassari) towards Olmedo. The *Amphiope*-bearing outcrop, belongs to the Calcari di Mores Formation, late Burdigalian-early Langhian (Carmignani et al., 2001).

TYPE MATERIAL. Lovisato (1911) did not designated a holotype nor detailed the composition of the type-series. According to Comaschi Caria (1955) all those specimens were lost; they were not traced by the authors at the UNICA. The validity of *A. montezemoloi* is still debated, since it has been synonymised with other *Amphiope* species, and the plate patterns were not described. Thus, a neotype is herein designated.

Neotype: MAC code PL1827 (Plate 3 Fig. 1a, b). It consists of a large complete specimen with oral structure partially visible (TL = 116, TW = 133, TH = 10, L11 = 14 mm). It comes from Stazione di San Giorgio, Sassari, the type locality of this species (40°41'13.68" N, 8°27'03.41" E), from the Calcari di Mores Formation.

EXAMINED MATERIAL. The studied material includes also 2 large test fragments from the type-locality (PL1828-9) and 3 specimens (PL1674-6) from Bonnanaro (Sassari).

REVISED DIAGNOSIS. Large sized species with low lateral profile and very large, subcircular to slightly transversely elongate, lunules. Frontal petal longer than the others. In the oral interambulacrum 5, plate 2b very elongate and only 2 post-basicoronal plates present in column 5a. Ambulacral basicoronal circlet very small. Internal structure reduced, central cavity with starring outline.

DESCRIPTION. Large sized test with transversely elongate and anteriorly restricted outline. Test very low (mean TH = 9.8% TL), almost flattened adapically. Margin posteriorly sharp, anteriorly more rounded and 3–3.5 mm thick.

Ambulacra. Frontal petal longer than the posteriors. Poriferous zones depressed; interporiferous zones slightly raised. Lunules very large, subcircular to broad elliptical with moderately transversely elongate outline. Ambulacra slightly depressed adorally along their central suture.

Interambulacra. The first post-basicoronal plate (2b) in the oral interambulacrum 5 is very elongate (Plate 3 Figs. 2a, b) and plate 2a is close to the posterior margin. Three post-basicoronal plates are present in column 5b, only two plates in column 5a.

Periproct. Small (mean diameter = 1.7% TL), rather close to the posterior test margin and located along the suture 2a-3b.

Internal structure. Rather complex but reduced, with thin shell and large spaces between the calcite elements comprising the buttress system (Plate 3 Figs. 5a, c). Central cavity large (Plate 3 Figs. 4, 7b) with flat and thin floor. On the ceiling, the interporiferous areas of the petals are convex, the poriferous areas slightly concave. Peripheral ballast system dense towards the ambitus.

Other features as for the genus. See Table 3 for descriptive statistics.

REMARKS. Large-sized test and broad subcircular to elliptical lunules (Lovisato, 1911) are confirmed by this study as distinctive features of *A. montezemoloi*. The other "diagnostic" characters stated in the original description cannot provide a clear separation from the other examined species.

In particular, the "irregularities on the aboral surface" described by Lovisato (1911) were not observed in any specimen. The apical disc is "eccentric towards the anterior test edge", but the measures of the two specimens reported by Lovisato (1911), as well as the mean of L4 in the examined sample of *A. montezemoloi*, almost correspond to those of *A. lovisatoi* and *Amphiope* sp. 2 (see Table 3).

A. montezemoloi was placed into synonymy with *A. bioculata* by Comaschi Caria (1955), Philippe (1998) and Kroh (2005). However, since at present a comparison with *A. bioculata* based on the structural characters is not possible, the separation between the two is herein maintained.

OCCURRENCE IN SARDINIA. San Giorgio and Bonnanaro (Sassari), Calcari di Mores Formation, late Burdigalian-early Langhian.

Amphiope nuragica (Comaschi Caria, 1955)
Plate 2 Figs. 1–13

1955. *Echinodiscus* (*Amphiope*) *nuragica* Comaschi Caria - Comaschi Caria, p. 186, pl. 1

1955. *Echinodiscus* (*Amphiope*) *deydieri* Lambert - Comaschi Caria, p. 186, pls. 2-3

1955. *Echinodiscus* (*Amphiope*) *transversivora* Lambert - Comaschi Caria, p. 187, pl. 4

1955. *Echinodiscus* (*Amphiope*) *pallavicinoi* Lovisato - Comaschi Caria, p. 188, pls. 5-6, pl. 13, fig. 2

1955. *Echinodiscus* (*Amphiope*) *calvii* Lovisato - Comaschi Caria, p. 188, pls. 7-8, pl. 13, fig. 1

1955. *Echinodiscus* (*Amphiope*) *lovisatoi* Cotteau - Comaschi Caria, p. 189, pl. 9; Pl. 11, fig. 2, pl. 12

1955. *Echinodiscus* (*Amphiope*) *dessii* Lovisato - Comaschi Caria, p. 190, pl. 10, pl. 11, fig. 1.

TYPE MATERIAL. Holotype (UNICA code 9CC.8-10504; Plate 2 Figs. 1a, b and 9). TL = 106, TW = 107, TH = 16 mm. It was the sole specimen attributed to this species by Comaschi Caria (1955).

TYPE-LOCALITY AND HORIZON. Layer I of Cuccuru Tuvullao (Cagliari; 39°47'18.88" N, 9°26'55.54" E), corresponding to facies "B" of Mancosu & Nebelsick (2013), Nurallao formation, Arenarie di Serralonga member, late Chattian-early Aquitanian.

EXAMINED MATERIAL. Two additional whole tests from C. Tuvullao I (UNICA, code 3CC and 6CC-10503). Nineteen specimens and 66 large test fragments from the same layer are housed at the MAC (PL1590-1, PL1678-80, PL1684, PL1727, PL1820, PL1829; PL1835-1844).

REVISED DIAGNOSIS. Test high, with narrow and transversely elongate lunules. Petal surface convex, including the poriferous areas. High number of plates in ambulacral and interambulacral columns. Three to four post-basicoronal plates in each column of the oral interambulacrum 5. Periproct close to the conjunction of plates 2a/2b/3a, or more posteriorly located. Internal support system strongly developed, with thick shell and roundish outline of the central cavity.

DESCRIPTION. Medium to large sized test. Outline subcircular in the holotype, but more frequently transversely elongate and restricted anteriorly (Pl. 2 Figs. 5-7). Maximal width located subcentrally. Test high (mean TH = 14.2% TL). Marginal indentations slightly developed in ambulacra II and IV, shallow notches may occur also in ambulacra I, III, V and interambulacra 1 and 4. A shallow but distinct anal notch may be present. Posterior edge thin, the anterior margin is thicker.

Ambulacra. Petals almost closed distally (Plate 2 Fig. 12), the frontal one slightly longer than the others. Maximal petal width about one half to two-thirds of petal length. External petal surface slightly raised and convex, including the interporiferous zones. Angle between the axis of posterior petals large: mean $\alpha = 76°$, against a mean of 71° at the other localities. A transversely elongate lunule is present in each posterior ambulacrum. Shape and size of lunules variable (Pl. 2, Figs. 13a–d). They are commonly narrow (Plate 2 Fig. 13b) to rather broad elliptical (Plate 2 Fig. 13a), seldom sub-polygonal (Plate 2 Fig. 7). A small protuberance is present along the internal margin of the lunules in the holotype and in another specimens (Plate 2 Figs. 1, 3). Ambulacra slightly depressed adorally along their central suture. Ambulacral basicoronal circlet rather large.

Interambulacra. There are 16–20 plates in each column of interambulacra 1, 4, 5, as well as in ambulacra I and V; 14–16 plates in interambulacra 2 and 3 and in ambulacra II, III and IV. Adorally, at least 3, frequently also 4, post-basicoronal plates present in each column of the interambulacral column 5a adorally (Plate 2 Fig. 1b, 3, 4).

Peristome. Small (mean diameter = 3.3% TL).

Periproct. It opens along the distal half of the suture 2a/3b, close to the conjunction point 2a/3b/3a (as in the holotype, compare Plate 2 Fig.

1b, 2b) or more posteriorly located (Plate 2 Fig. 3). It is close to the posterior test edge (mean L11 = 9.1 % TL).

Internal structure. Well developed, with thick shell and spaces between elements narrower than the elements comprising the buttress system (Plate 2 Fig. 11). The floor of the central cavity in the inter-ambulacra begins to thicken close to the peristome and gradually rises, extending radially towards the first pillars of the radial supports (Plate 3 Fig. 7c). Central cavity with a rough sub-circular outline.

Other features as for the genus. See Table 3 for descriptive statistics.

REMARKS. The noticeable test height (TH = 14.2% TL), the periproct close to the posterior edge (L11 = 9.1% TL) and the characteristic shape and proportion of lunules, stated by Co-maschi Caria (1955) for A. nuragica, are confirmed by this study as valid distinctive characters. The other "diagnostic" features are variable in the stud-ied sample and cannot provide a clear separation from the other examined species. In particular, ir-regularities in the lunules outline, as the promi-nences described by Comaschi Caria (1955), occur randomly in other species (Plate 1 Fig. 7e; Plate 2 Figs. 1, 3) and have no taxonomic value. The morphology and the plate patterns of two spec-imens assigned by Comaschi Caria (1955) to A. dessii and A. calvii (UNICA, code 6CC-10503 and 3CC, respectively), correspond to those of A. nuragica and are therefore assigned to this species. The same case occurs with specimens bearing external features corresponding to A. deydieri, A. transversivora, A. pallavicinoi, A. calvii and A. lovisatoi, all species recorded from this locality by Comaschi Caria (1955); additionally they are not statistically separable from the others from C. Tuvullao I.

OCCURRENCE IN SARDINIA. Cuccuru Tuvullao (Cagliari), Nurallao formation, Arenarie di Serra-longa member, late Chattian-early Aquitanian.

Amphiope sp. 1
Plate 3 Figs. 8–10

EXAMINED MATERIAL AND HORIZON. 3 specimens (MAC code PL1681, PL1685 and PL1834) and 1 test fragment (PL1684), from layer II of C.Tuvullao

(Cagliari, 39°47'18.88"N, 9°26'55.54"E), corre-sponding to facies "C" of Mancosu & Nebelsick (2013), Nurallao formation, Arenarie di Serralonga member, late Chattian-early Aquitanian.

DESCRIPTION. Middle to large sized test with thick margin. Outline transversely elongate and slightly anteriorly restricted. Maximal width located subcentrally. Test very high (mean TH = 20.7% TL), with maximal height slightly anterior of the apical disc (Plate 3 Fig. 8c). Marginal indentations slightly developed in ambulacra II, III and IV. Faint notches may occur also along the posterior test edge, in ambulacra I and V and interambulacra 1 and 4.

Ambulacra. Frontal petal distinctly longer than the posteriors (mean L9 = 79.1% L5). Maximal petal width about one half to two-thirds of petal length. Poriferous zones depressed; in-terporiferous zones slightly raised. Lunules tran-sversely elongate, narrow elliptical and close to the tips of the posterior petals (mean L3 = 4.6% TL). Ambulacra slightly depressed adorally along their central suture. Ambulacral basicoronal cir-clet small.

Interambulacra. Adorally, only two, maximum three, post-basicoronal plates are present in each col-umn of interambulacrum 5 (Plate 3 Figs. 9b, 10b).

Periproct. Bounded by the first pair of post-basicoronal plates 2a/2b (Plate 3 Figs. 9b, 10b) and far from the posterior test margin (mean L11 = 13.8% TL).

Other features as for the genus. See Table 3 for descriptive statistics.

REMARKS. The specimens from C. Tuvullao II stand apart from all the others examined from Sar-dinia by their much higher test, more centrally lo-cated apical disc, frontal ambulacrum much longer than the posterior ones and lunules closer to the tips of the posterior petals.

In addition, it differs from A. nuragica by the presence of only three post-basicoronal plates in each column of interambulacrum 5 adorally and the periproct bounded by the first pair of post-basi-coronal plates.

The plate patterns in oral interambulacrum 5 cor-respond to the drawings of A. bioculata reported by Durham (1955), Kroh (2005) and Pereira (2010), but the attribution of those schemes to the type-species

is doubtful since they were not based on topo-typic material. Besides, the specimens of C. Tuvullao II differ by more transversely elongate lunules.

OCCURRENCE IN SARDINIA. Cuccuru Tuvullao (Cagliari), Nurallao formation, Arenarie di Serralonga member, late Chattian-early Aquitanian.

Amphiope sp. 2
Plate 4 Figs. 1–15

EXAMINED MATERIAL. Ten complete specimens (MAC PL343, PL547-553, PL1665, PL1836) and ten fragments from Bancali (Sassari, 40°43'55.66"N, 8°26'55.54" E), collected in a bioclastic sandstone at "outcrop 2" described by Stara et al. (2012), attributed to the Calcari di Mores Formation, late Burdigalian-early Langhian.

DESCRIPTION. Middle to very large sized test, with rather thin margin. The test width reached up to 133 mm in complete specimens, but some fragments points to complete test with length up to about 170 mm. Outline slightly transversely elongate and restricted anteriorly (Plate 4 Figs. 1–3). Maximal width located subcentrally. Maximum test height slightly anterior of the apical disc (Plate 4 Figs. 4–6). Marginal indentations well developed in ambulacra II and IV, faint indentations may occur also in ambulacra I, III and V and interambulacra 1 and 4. Oral side flat or slightly concave. Food groves well developed (Plate 4 Figs. 2, 3), bifurcating at the edge of the basicoronal circle. Posterior pair of food grooves running around the lunules, not reaching the margin; finer distal branches well developed.

Apical system. Distinctly anterior to centre (mean L4 = 59.7% TL).

Ambulacra. Frontal petal slightly longer than the others.Maximal petal width about one half to two-thirds of petal length. Poriferous zones depressed; surface of the interporiferous zones slightly convex. A broad and slightly transversely elongate lunule is present in each posterior ambulacrum. Lunules commonly subcircular (Plate 4 Figs. 14c, d) to broad elliptical (Plate 4 Fig. 14e). Ambulacra slightly depressed adorally along their central suture. Ambulacral basicoronal circlet rather large (mean L13 = 11.3% TL).

Interambulacra. There are 14–16 plates in each column of interambulacra 1, 4, 5 and ambulacra I and V, 12-14 plates in interambulacra 2 and 3 and in ambulacra II, III and IV. Only 3–4 post-basicoronal plates present in each column of oral interambulacrum 5 (Plate 4 Figs. 11, 12).

Peristome. Small (mean diameter = 2.8 % TL).

Periproct. Small (mean diameter = 2% TL), located between the second pair of post-basicoronal plates (Plate 4 Figs. 11, 12) and rather far from the posterior test margin.

Internal structure. Well developed, with rather thick shell wall and spaces between elements narrower than the elements comprising the buttress system. Central cavity with almost starring outline and interambulacral radial supports extending towards the centre.

Other features as for the genus. See Table 3 for descriptive statistics.

REMARKS. *Amphiope* sp. 2 differs statistically from *A. montezemoloi* by more elevate test, larger ambulacral basicoronal circlet and smaller lunules; it has also a stronger internal structure. The same differences separate *Amphiope* sp. 2 from *A. lovisatoi*; additionally, the specimens from Chiaramonti are smaller and the periproct, though bounded by plates 2a/3b as well as in the sample of Bancali, is closer to the conjunction point 2a/3b/3a.

The closely related specimens from Ardara (Sassari) likely belong to this species, though a larger sample from this locality is needed to confirm this hypothesis.

OCCURRENCE. Bancali, probably also Ardara, (Sassari), Calcari di Mores Formation, Late Burdigalian-early Langhian.

STRATIGRAPHICAL DISTRIBUTION AND EVOLUTIVE TRENDS

The genus *Amphiope* is represented in Sardinia by forms with rounded or transversely elongate lunules, only. The first records of *Amphiope* with axial lunules are dated to the middle Oligocene of the Gulf of Biscay, Val Bormida (Piedmont, Italy) and Libya, whereas *Amphiope* with transverse lunules appeared in the late Oligocene-early Miocene in the area between the Gulf of Biscay and the intra-AlCaPeKA Basin (Stara & Rizzo, 2013). At that
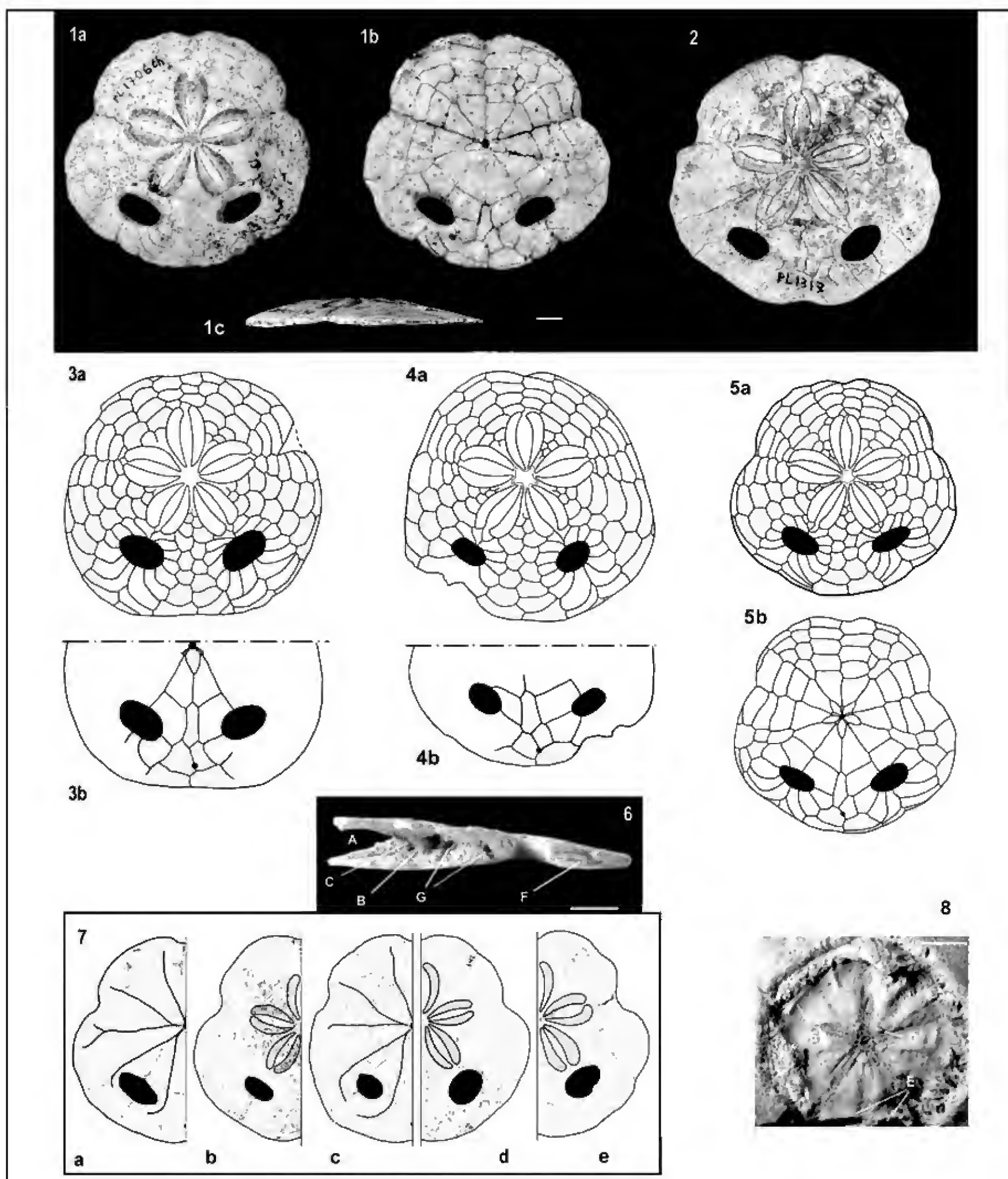
Plate 1. *Amphiope lovisatoi* Cotteau, 1895, Calcari di Mores Formation, late Burdigalian, Chiaramonti (Sassari). Figs. 1a–c Neotype (PL1706, TL = 73 mm), aboral (a), oral (b) and antero (to the left)-posterior (to the right) lateral view (c). Fig. 2. Aboral view of PL1317 (MAC code), TL = 82 mm. Figs. 3a, b. Plate patterns of PL1704 (TL = 82 mm); a) aboral side, b) oral side. Figs. 4a, b. Plate structure of PL1574 (TL = 80 mm); a) aboral side, b) oral side. Figs. 5a, b. Plate patterns of PL1706 (TL = 73 mm); a) aboral side, b) oral side. Fig. 6. Internal structure: cross-section along the radial axis of ambulacrum I. Figs. 7a-e. Variation range of test outline and lunules shape. All specimens in aboral view, if not otherwise specified. a) PL1308 (oral view; TL = 78 mm). b) PL1312 (TL = 76.2 mm). c) PL1311 (oral view; TL = 85 mm). d) PL1306 (TL = 89 mm). e) PL1303 (TL = 83.5 mm). Fig. 8. Internal view of oral surface, with almost flat floor and straight walls (E) delimiting the subpentagonal outline of the central cavity. In Figs. 6 and 8: A = central cavity, B = first peripheral elements (pillars or walls), C = radial cavity of the interambulacrum 5 leading to the periproct, D = lantern supports, E = straight walls at the periphery of the central cavity, F = massive peripheral support system, G = small cavities. Scale bar equals 1 cm.
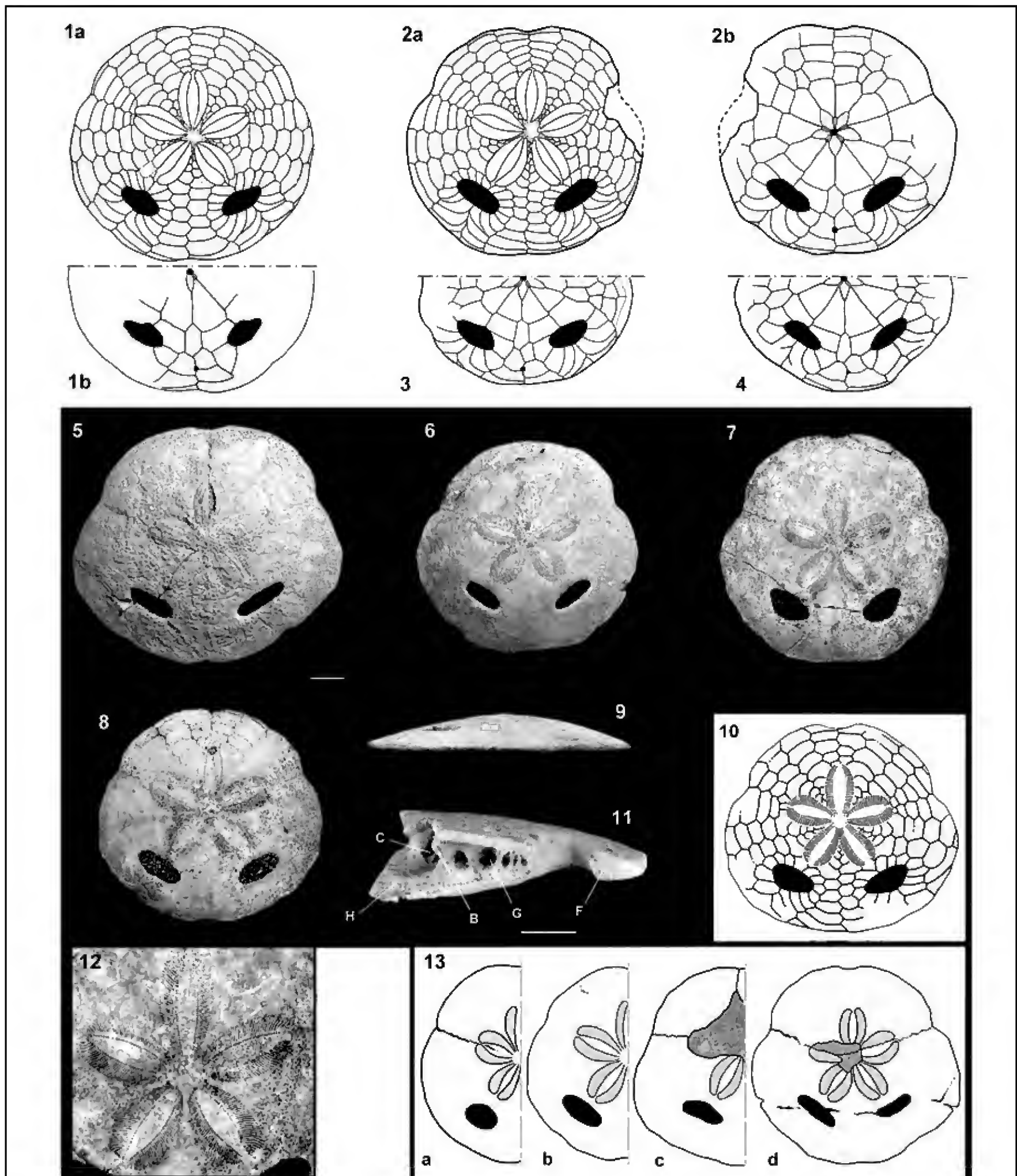
Plate 2. *Amphiope nuragica* (Comaschi Caria, 1955), Nurallao formation, late Chattian-early Aquitanian, Cuccuru Tuvullao (Cagliari). Figs. 1-4, 10 Plate structure drawings with interambulacral plates shaded grey. 1) Holotype (UNICA code 9CC.8; TL = 100 mm), aboral (1a) and oral (1b) views. 2) PL1680 (TL = 100 mm), aboral (2a) and oral (2b) views. 3) PL1591 (TL = 81 mm), oral view. 4) PL1684 (TL = 91 mm), oral view. 10) PL1835 (TL = 89 mm), aboral view. Fig. 5. PL1836 (TL = 93 mm), aboral view. Fig. 6. PL1835 (TL = 89 mm), aboral view. Fig. 7. PL1837 (TL = 88.5 mm), aboral view. Fig. 8. PL1838 (TL = 82 mm), aboral view. Fig. 9. Antero (to the right)-posterior (to the left) lateral view of PL1820 (TL = 98.2 mm). Fig. 11. Close up view of a cross-section through the radial axis of the ambulacrum I. B = first peripheral elements (pillars), C = radial cavity of the interambulacrum 5 leading to the periproct, F = massive peripheral support system, G = small cavities, H = floor of the central cavity. Fig. 12. Close up of the petals (PL1835, TL = 89 mm). Figs. 13a-d. Variability of test outline and lunules shape. All specimens in aboral view. a) PL1839 (TL = 59.4 mm), b) PL1838 (TL = 82 mm), c) PL1840 (TL = 83.6 mm), d) PL1841 (TL = 98.2 mm). Scale bar equals 1 cm.
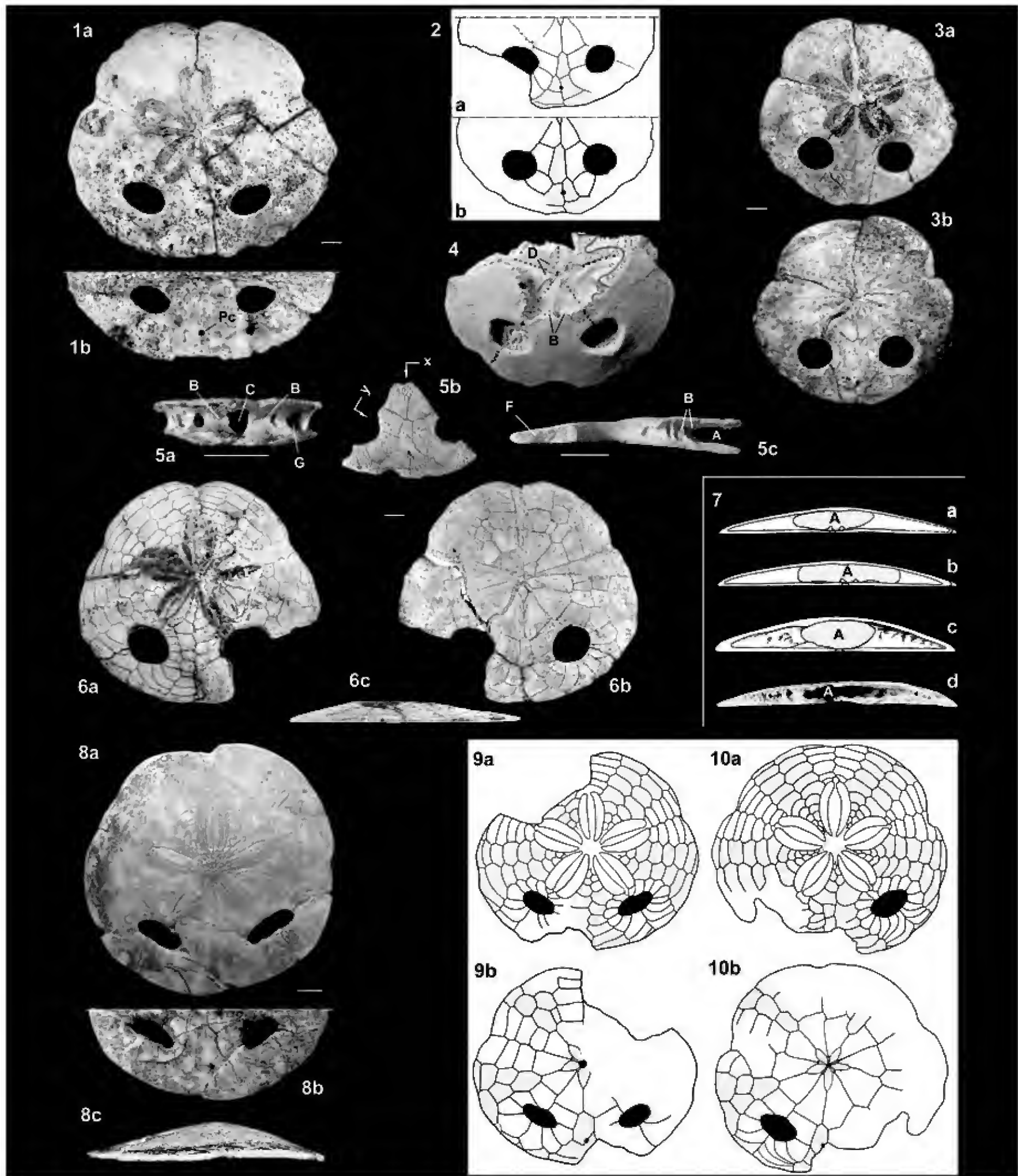
Plate 3. *A. montezemoloi*, San Giorgio and Bonnanaro (Sassari). Figs. 1a-b. Neotype (PL1827): aboral (a) and adoral (b) views , TL=121 mm. San Giorgio. Figs 2a-b. Oral plating structure of PL1675 (a) and PL1676 (b). Bonnanaro. Figs. 3a, b. Specimen PL1676 (TL=90 mm): aboral (a) and oral (b) views. Bonnanaro. Fig. 4. Aboral view of PL1828; margins of the central cavity marked as dotted lines. San Giorgio. Figs. 5a–c. Test fragment (PL1830): adoral (b) and internal views taken from points x (a) and y (c), respectively. Bonnanaro. Figs. 6a–c. Aboral (a), oral (b) and antero (to the left)-posterior (to the right) lateral (c) views of PL1675 (TL=112 mm). Bonnanaro. Figs. 7a–d. Scheme of the internal structure in an antero (to the right)-posterior (to the left) axial section of specimens from: a) *A. montezemoloi*, San Giorgio, b) *A. lovisatoi*, Chiaramonti, c) *A. nuragica*, C.Tuvullao, d) *Amphiope* sp. 2, Bancali. *Amphiope* sp. 1, Nurallao formation, late Chattian-early Aquitanian, of Cuccuru Tuvullao (Cagliari). Figs. 8a–c. PL1834 (TL=95.5 mm); aboral (a), adoral (b) and antero (to the right)-posterior (to the left) lateral (c) views, respectively. Figs. 9a, b. Plating patterns of PL1681 (TL=90 mm); a) aboral side, b) oral side. Figs. 10a, b. Plating patterns of PL1685 (TL=101 mm); a) aboral side, b) oral side. In Figs. 5a–c: A = central cavity, B=first peripheral elements (pillars or straight walls), C=radial cavity of the interambulacrum 5 leading to the periproct, F=massive peripheral support system, G=small cavities. Scale bar equals 1 cm.
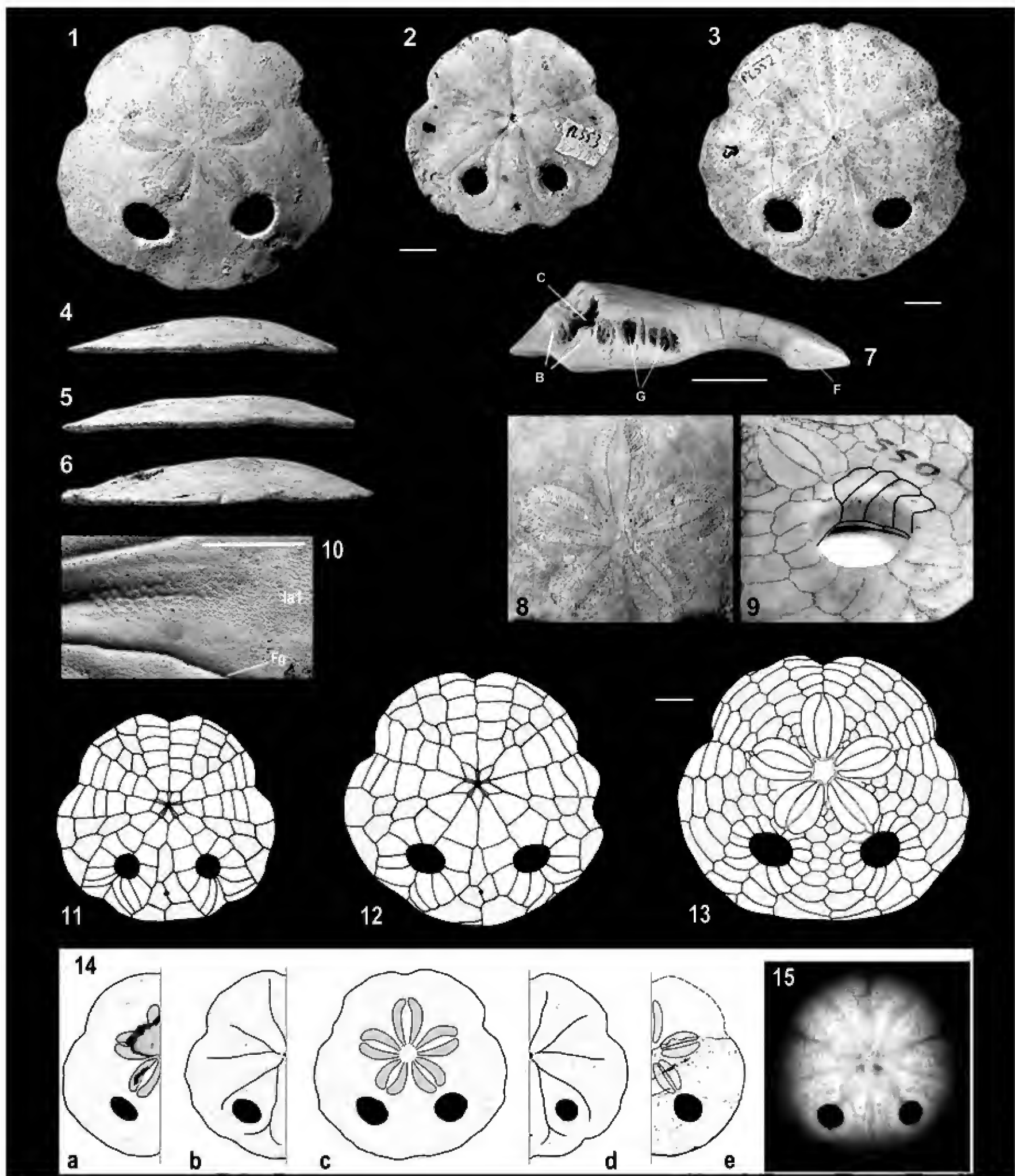
Plate 4. *Amphiope* sp. 2, Calcari di Mores Formation, late Burdigalian-early Langhian, Bancali (Sassari). Figs. 1–3. 1) PL343, TL = 73 mm). 2) PL553, adoral view (TL=55.8 mm). 3) PL552, adoral view (TL=73.4 mm). Figs. 4-6. Antero (to the right)-posterior (to the left) lateral views of PL343 (4), TL=73 mm, PL550 (5), TL=79.5 mm and PL551 (6), TL=88.5 mm. Fig. 7. Close up view of the internal structure: cross-section of a test fragment along the radial axis of ambulacrum I. B = first pillars in the radiating buttresses of interambulacrum 5, C=radial cavity of the interambulacrum 5 leading to the periproct, F=massive peripheral support system, G=small cavities. Figs. 8-9. PL550 (TL=79.5 mm). 8) close up view of the petals; 9) plating scheme of a lunule (oblique view), with cross-linked wall. Fig. 10. Close up view of the tuberculation in the oral interambulacrum 1; fg=food groove. Figs. 11-13. Plate diagrams, with interambulacral plates shaded grey. Oral side: 11) PL551Ba, TL=88.5 mm; 12) PL552, TL=73.4 mm. Aboral side: 13) PL553, TL=55.8 mm. Figs. 14a-e. Variation range of test outline and lunules shape. All specimens in aboral view, if not otherwise specified; a) PL548 (TL=93 mm), b) PL552 (oral view; TL=73.4 mm), c) PL550 (TL=79.5 mm), d) PL553Ba (oral view; TL=55.8 mm), e) PL1281 (TL=81.7 mm). Fig. 15. X-ray photograph (PL549), showing the starring outline of the central cavity. Scale bars equal 1 cm.

time Sardinia begun to separate from Europe and the progressive marine ingression transformed it into an archipelago surrounded by an epicontinental sea (Gattaceca et al., 2007). *A. nuragica* and *Amphiope* sp. 1, from the late Chattian-early Aquitanian Nurallao formation, inhabited shallow water environments of that sea and represent the earliest record of this genus in Sardinia and one of the oldest record of *Amphiope* with transverse lunules (Stara et al., 2012). The resemblance, based on comparison of test and lunules features alone, with the almost coeval population "A" of *A. bioculata* described by Philippe (1998) from the Aquitanian of the Rhône Basin, suggests that at that time closely related, may be the same, species of *Amphiope* inhabited Sardinian and Provencal shallow environments.

In the middle Miocene Sardinia was encircled by a deep sea. During that period *Amphiope* developed into new species (Fig. 6): *A. lovisatoi*, *A. montezemoloi* and *Amphiope* sp. 2 of the Burdigalian-early Langhian of the Calcari di Mores Formation, and *Amphiope* sp. of the Early Serravallian Capo Frasca Sud Formation (Funedda et al., 2000); Spano et al., 2002). Lovisato (1914) cited *Amphiope* also from a "*sottile banco di calcare breccioso compattissimo, sotto al calcare argilloso*" outcropping at Monte S. Michele (Cagliari, n. 24 in Fig. 1). This sediment corresponds to the "Pietra Forte" belonging to the Calcari di Cagliari Formation, dated to the late Tortonian-early Messinian Cherchi et al., 1978), thus representing, so far, the most recent population of the genus *Amphiope*.

A major evolutionary change observed in the studied sample points to the progressive reduction and the increasing complexity of the internal support system. Thus, the dense and strong internal buttress and the thick shell of *A. nuragica*, should be regarded as primitive characters in *Amphiope* with transverse lunules. A decreasing number of plates in the ambulacral and interambulacral columns and the progressive migration of the periproct towards the peristome, from plates 3b/3a in the Aquitanian *A. nuragica*, to the distal part of the suture 2a/3b in the Burdigalian *A. lovisatoi*, to the proximal part of 2a/3b in the early Langhian *A. montezemoloi* and *Amphiope* sp. 2, are also observed (Fig. 6). The only exception to the last two trends is represented by the "ancient" *Amphiope* sp.1 (Fig. 6), with the pe-

riproct bounded by the first post-basicoronal plates (2a/2b) and a low number of plates in the oral interambulacrum 5.

Paleoecological data reported for the *Amphiope*-bearing Sardinian localities (Stara et al., 2012) indicate that *Amphiope* was a deposit feeder, living in shallow sandy settings, with middle to high water energy and tropical climate.

CONCLUSIONS

The examined material shows that previously described criteria used to distinguish between the fossil species of *Amphiope* cited in Sardinia are not sufficiently diagnostic, mainly due to the marked intra-specific variation of the external test features.

The well preserved specimens available to study from this region enable to describe the plate patterns and the internal test support system. Based on these features and the results of the morphometric analyses, three different species are recognized in the examined material: *A. nuragica*, late Chattian-early Aquitanian of Cuccuru Tuvullao (Cagliari), *A. lovisatoi*, late Burdigalian of Chiaramonti (Sassari), *A. montezemoloi*, late Burdigalian-early Langhian of San Giorgio and Bonnanaro (Sassari). Two groups of specimens from the late Chattian-early Aquitanian of C. Tuvullao (layer II) and the late Burdigalian-early Langhian of Bancali, though well differentiated, are assigned to *Amphiope* sp. 1 and *Amphiope* sp. 2 respectively, and left in open nomenclature due to the scarcity of the available material.

The stratigraphical distribution of *Amphiope* in Sardinia ranges from the late Chattian-early Aquitanian of Cuccuru Tuvullao, which represents one of the earliest records of *Amphiope* with transverse lunules in the Mediterranean, to the late Tortonian-early Messinian of Monte San Michele (Cagliari), the last being the most recent record of this genus.

The main evolutionary trends observed in the studied sample from Sardinia are the progressive reduction and the increasing complexity of the internal support system of the test. Also a decreasing number of plates in the ambulacral and interambulacral columns and the approaching of the periproct towards the peristome are observed, though they need confirmation based on a larger fossil sample.

The results of this study highlight the validity of the structural characters as taxonomic tools at the

	Species	N	Mean (mm)	Range (mm)	S.E
TL	A. lovisatoi	38	76.0	52-100	1.64
	A. montezemoloi	4	109.0	90-121	6.65
	A. nuragica	20	92.7	81-100	1.33
	Amphiope sp. 1	3	95.5	90-101	3.17
	Amphiope sp. 2	9	95.9	55.8-137	8.71

	Species	N	Mean % Dap	Range % Dap	S.E
TW	A. lovisatoi	38	105.4	94-113	0.69
	A. montezemoloi	4	105.7	100-110	2.10
	A. nuragica	20	106.3	101-116	0.77
	Amphiope sp. 1	3	109.3	102-114	3.71
	Amphiope sp. 2	9	104.7	102-110	0.87
TH	A. lovisatoi	36	10.2	6.8-15.1	0.29
	A. montezemoloi	4	9.8	8.3-12.2	0.99
	A. nuragica	20	14.2	10.5-17.2	0.38
	Amphiope sp. 1	3	20.7	19.8-22.2	0.77
	Amphiope sp. 2	9	12.3	8.8-14.6	0.58
L1	A. lovisatoi	38	11.2	8.3-15.1	0.26
	A. montezemoloi	4	14.4	11.6-16.7	1.12
	A. nuragica	20	8.2	6.0-11.2	0.37
	Amphiope sp. 1	3	9.5	8.2-11.9	1.22
	Amphiope sp. 2	9	11.7	10.8-13.9	0.44
L2	A. lovisatoi	38	17.1	11-22	0.42
	A. montezemoloi	4	16.9	14.2-18.3	0.93
	A. nuragica	20	18.0	14.1-23.5	0.61
	Amphiope sp. 1	3	18.9	17.8-20.8	0.95
	Amphiope sp. 2	9	15.0	11.1-18.2	0.78
L3	A. lovisatoi	37	5.7	2.8-8.5	0.21
	A. montezemoloi	4	5.0	3.9-6.6	0.60
	A. nuragica	20	5.3	2.2-8.0	0.35
	Amphiope sp. 1	3	4.6	3.3-5.4	0.64
	Amphiope sp. 2	9	4.8	3.3-6.8	0.49
L4	A. lovisatoi	37	59.4	51.9-65.2	0.51
	A. montezemoloi	4	59.3	55.1-62.2	1.52
	A. nuragica	19	57.4	50.0-63.0	0.68
	Amphiope sp. 1	3	53.3	49.5-57.6	2.35
	Amphiope sp. 2	9	59.7	53-66	1.42
L5	A. lovisatoi	37	24.1	20.8-28.5	0.34
	A. montezemoloi	4	24.7	22.8-26.6	0.98
	A. nuragica	19	25.2	23.0-27.2	0.30
	Amphiope sp. 1	3	27.7	26.7-28.7	0.58
	Amphiope sp. 2	9	24.7	21.9-29.0	0.74
L6	A. lovisatoi	37	14.8	11.8-17.3	0.20
	A. montezemoloi	4	14.7	13.2-15.6	0.53
	A. nuragica	19	14.1	11.1-16.5	0.27
	Amphiope sp. 1	3	15.3	14.4-16.8	0.75
	Amphiope sp. 2	9	15.1	12.8-16.3	0.43
L9	A. lovisatoi	35	22.9	19.3-26.0	0.30
	A. montezemoloi	4	21.4	20.0-22.7	0.59
	A. nuragica	18	22.4	18.4-26.0	0.47
	Amphiope sp. 1	3	21.9	18.8-24.4	1.64
	Amphiope sp. 2	8	21.7	17.9-24.2	0.80
L10	A. lovisatoi	35	15.2	12.5-19.0	0.25
	A. montezemoloi	4	13.8	13.4-14.2	0.27
	A. nuragica	18	14.3	11.0-16.2	0.03
	Amphiope sp. 1	3	13.9	11.9-15.6	1.07
	Amphiope sp. 2	8	14.4	11.6-15.8	0.42
L11	A. lovisatoi	4	12.0	9.8-14.0	0.91
	A. montezemoloi	3	12.0	12.5-14.9	0.63
	A. nuragica	17	9.1	6.3-12.8	0.38
	Amphiope sp. 1	3	13.8	12.2-15.8	1.06
	Amphiope sp. 2	9	13.0	10.0-15.8	0.69

Table 3. Descriptive statistics of *Amphiope* from Sardinia. N = number of specimens, S.E. = standard error.
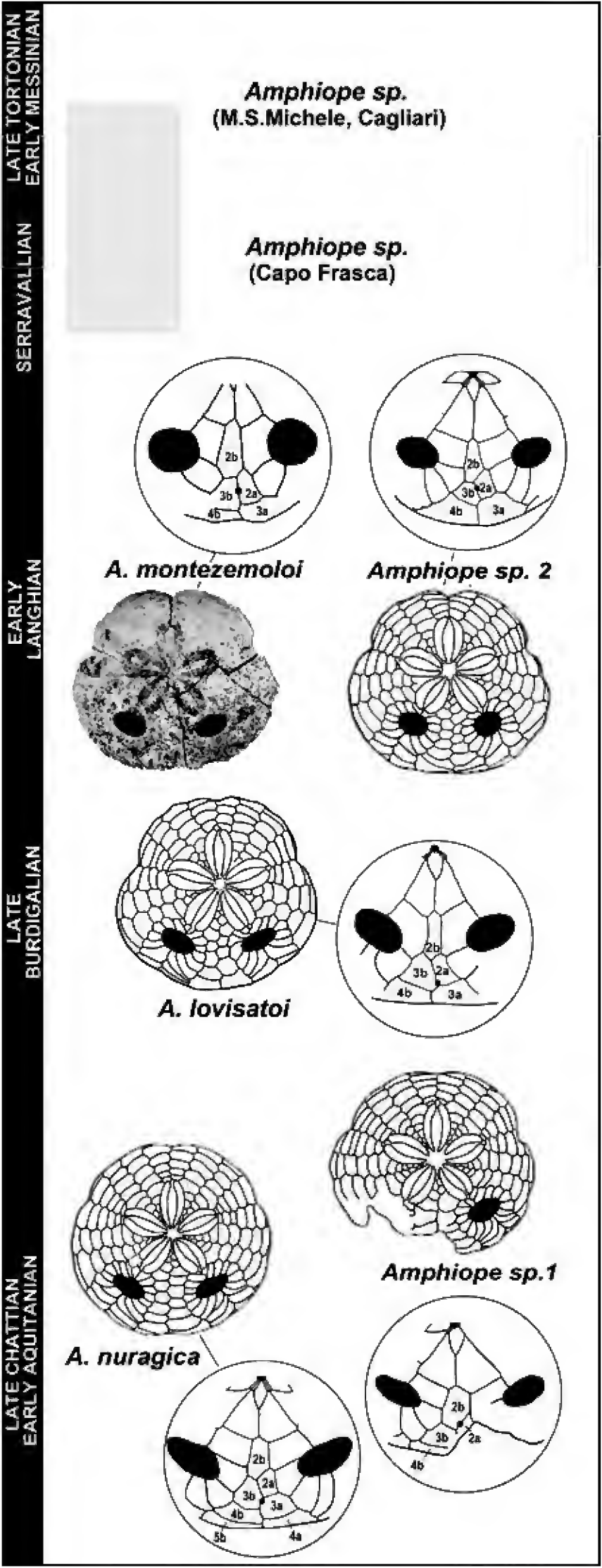

Figure 6. Scheme of the major evolutionary trends observed in the studied sample of *Amphiope* from Sardinia, with the only exception of *Amphiope* sp. 1. Over time the number of plates in the oral interambulacrum 5 decreases and the periproct migrates toward the peristome, in relation to post basicoronal plates number.

Morphological characters	A. lovisatoi Cotteau, 1895	A. montezemoloi Lovisato, 1911	A. nuragica (Comaschi Caria, 1955)	Amphiope sp.1	Amphiope sp.2
Test size (TL)	small (mean 76 mm)	large (mean 109 mm)	middle sized (mean 92.7 mm)	middle sized (mean 95.5 mm)	very large (> 130 mm)
Test height	low (H=10.2% Dap)	very low (H=9.8% Dap)	middle height (H=14.2% Dap)	very high (H=20.7% Dap)	middle height (H=12.3% Dap)
Test margin	thin	thin	middle thickness	rather thick	middle thickness
Lunules size and shape	small slightly elongate	very large almost subcircular	large narrow elliptical	large narrow elliptical	large subcircular-elliptical
Location of the periproct	distal half of the suture 2a/3b	halfway along the suture 2a/3b	close to the conjunction of plates 2a/3a/3b	bounded by plates 2a/2b	halfway along the suture 2a/3b
Number of plates in interambulacra 2, 3 and ambulacra II-IV	10-13	-	14-16	-	12-14
Number of post-basicoronals in oral interambulacrum 5a	2	2	3	2	2
Number of post-basicoronals in oral interambulacrum 5b	3	3	4	3	3
Central cavity	subpentagonal	starring	subcircular	subcircular	starring
Internal structure	light and complex	rather light, complex	simple and strong	simple and strong	rather strong
Other characteristics	- Shell very thin	- Shell thin - Plate 2b of oral interambulacrum 5 very elongate	- Shell thick - Petal surface convex, including the poriferous areas	- Shell very thick - Lunules very close to posterior petals - Apical disc more centrally located than the others - Frontal petal much longer than the posteriors	

Table 4. Specific characters in the studied species.

specific level in *Amphiope* and indicate that a review, based on these features, of the earlier described species of *Amphiope* is needed to improve the poorly resolved taxonomy of this genus and to bring light into the diffusion of *Amphiope* in the Mediterranean and in the eastern Atlantic.

ACKNOWLEDGEMENTS

tugal) provided us with a first version of the biometrical statistical analyses. We are grateful also to Davide Serra, for allowing access to the fossilifer-ous site of Cuccuru Tuvullao, and Mario Lai (3S, Laboratori Analisi Immagini, Capoterra), for providing the radiographs utilized in this work.

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Analysis on a sample *of Echinodiscus* cf. *auritus* Leske, 1778 (Echinoidea Clypeasteroida)

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ABSTRACT   In order to ascertain the extent of the natural intraspecific variability of living and fossil echinoids belonging to the family Astriclypeidae Stefanini, 1912, morphometric and structural aspects were examined in a number of specimens of extant *Echinodiscus* cf. *auritus* Leske, 1778, from Madagascar and Philippines. The data obtained will be compared, in a following work, with those of other echinoids belonging to the same family. The analysis of the results indicates, for the sample studied, a great variability in the length of the posterior ambulacral notches, in the petaloid length and in the position of the periproct respect to the posterior margin, while the study of the complete scheme of the plates has clarified the stability and constancy of some parts of this scheme and the variability of other. On the basis of these observations, it has been claimed that the variability of these measures is not so extensive as to affect or determine specific distinctions, if used without careful analysis of the plating pattern in particular in the interambulacrum 5 and in the ambulacra I and II. The results of these analyses, finally, suggests that these echinoids belong to a different genus, than *Echinodiscus* Leske, 1778.

KEY WORDS   Astriclypeidae; *Echinodiscus* cf. *auritus*; morphometric variability; Recent.

Received 25.06.2013; accepted 30.05.2014; printed 30.06.2014
Paolo Stara (ed.). Studies on some astriclypeids (Echinoidea Clypeasteroida), pp. 225–358

INTRODUCTION

The variability in shape of some parts of the test in echinoids belonging to family Astriclypeidae Stefanini, 1912, has been a problem discussed for a long time (Stara & Fois D., 2014). Considering the wide variability in the extinct genus *Amphiope* L. Agassiz, 1840, Philippe (1998), in the absence of comparative studies on the intraspecific variability in living echinoids belonging to the same family, poses in synonymy many *Amphiope* species present in the Miocene levels of the Rhône Basin (Southern

France). In fact, given the large variability in size and shape of the lunules of these echinoids, he concluded that most nominal species previously established should be in synonymy with the type species: *Amphiope bioculata* des Moulins, 1837. The same difficulties are also experienced by Stara & Borghi (2014) during the study of Sardinian's *Amphiope* species, some put in synonymy by Philippe (1998) and, later, also by other authors. In this case, however, the study of the species from Sardinia was addressed by analyzing both the variability of lunules, both the internal structure and the scheme of the

plates that compose the test, as already done by other authors for this family of echinoids (Durham, 1955; Kroh, 2005; Pereira, 2010).

Therefore, the goal of this work is to verify the extent of the morphometric variability in some echinoids belonging to the genus *Echinodiscus*, in order to compare it with that observed by Stara & Borghi (this volume) on a sample of at least a hundred of specimens of different species of *Amphiope* collected in a number of Oligo-Miocene Sardinian outcrops.

MATERIAL AND METHODS

The samples examined are housed in the collections of the Museo di Storia Naturale Aquilegia of Cagliari (acronym MAC). Being irregular echinoids in bilateral symmetry, with the symmetry plane passing along the line stoma - procto, we realize that it was the distance measured along the test length (TL) could provide the major reference point, according by Kier (1972) and Stara & Borghi (2014).

Therefore, specimens were ordered on the basis of the TL, as done previously by Lohavanijaya & Swan (1965), Alexander & Ghiold (1980) and Stelmle (1990).

We detected the structure of the test, showing the relative platings of the plates, as was done by Durham (1955), but including both faces of specimens. The internal structure was studied by sectioning the test, and by X-ray; 3 specimens from Mangili, 2 from Philippines were used for this purpose.

Because of the similarities between the two genera object of the parallel study, to reach homogeneity we use on *Echinodiscus* the same set of measurements used to collect data on *Amphiope* by Stara & Borghi (this volume) with the addition of some further measures, such as the attached drawings.

Morphological abbreviations (Fig. 1) ß angle between major axis of the two lunules; TL = Test Length; TW = Test Width; TH = Test Height; WA= ambulacral and interambulacral width at ambitus; L1-L2 = lunule length and width, respectively; L3 = distance between petal tip and corresponding lunule,
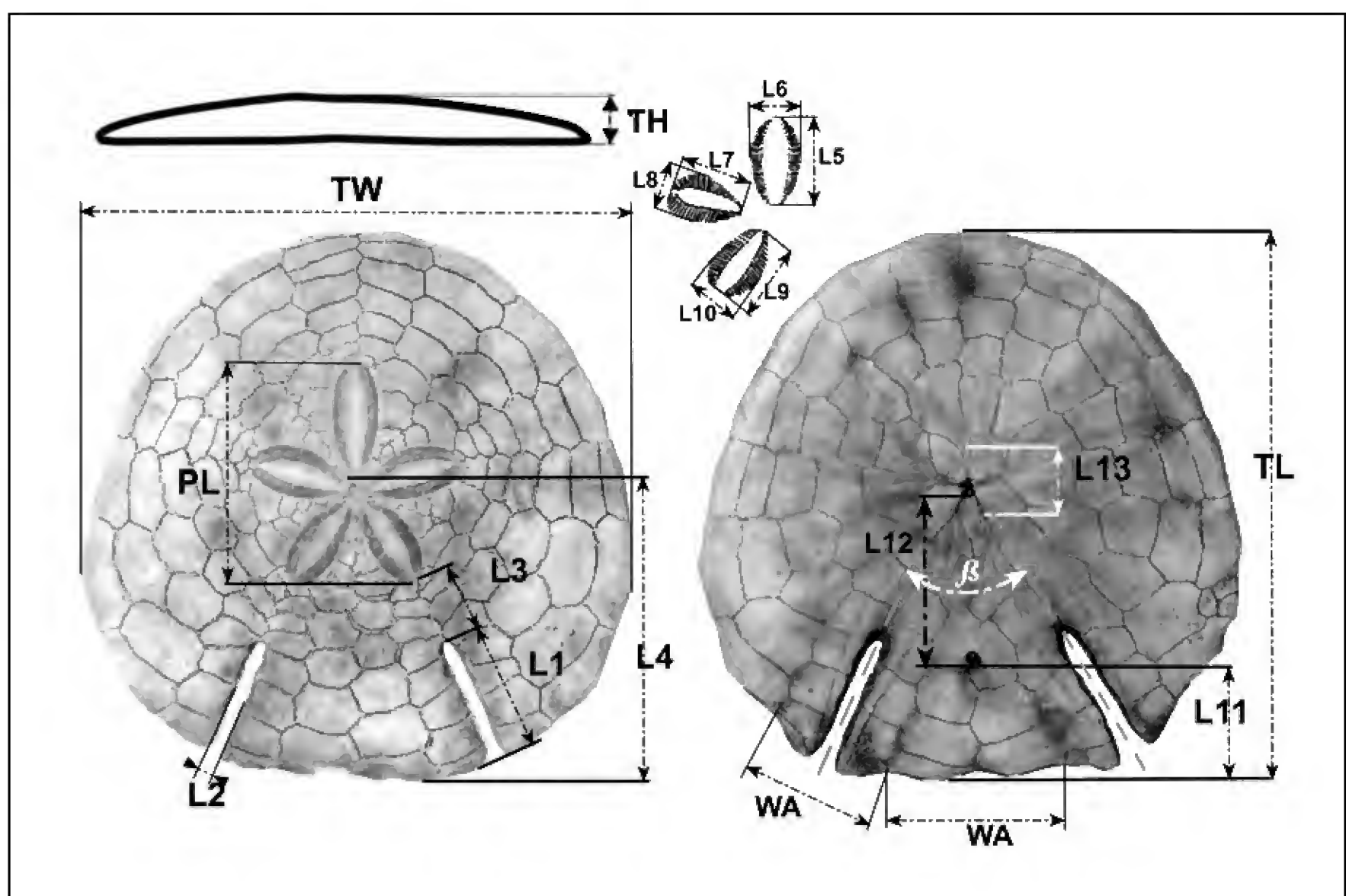

Figure 1. Biometric parameters measured in the studied samples.

L4 = distance apical system-posterior margin, L5–L6 = length and width of the frontal petal, respectively; L7-L8 = length and width of the anterior paired petal, respectively; L9-L10 = length and width of the posterior petal, respectively; L11 = distance between periproct and the posterior border of the test; L12 = distance between periproct and peristome, L13 = front-rear diameter of the basicoronal circlet. PL = Petalodium Length; ø pc = periproct diameter; ø ps = peristome diameter; Σ = summation. To reduce the lunules shape and dimension into a numeric value, we introduced a Shape Index (SI) corresponding to the ratio L2/L1 and a Width (wideness) Index (WI) corresponding to the formula (L1 + L2) / 2. In the chapters of the analysis/descriptions of samples/specimens, the interambulacrum 5 was abbreviated as inter 5.

Measurements were taken with caliper and/or metallic decimeter (with division to the millimeter) measures of TL and thickness of the anterior and posterior margins were taken in millimeter; all other linear measurements were reported as percentage TL; while the angular divergence between the axis of the notches, were detected in degrees, using a computer graphics program. The use of the percentages was adopted to decrease the influence of the variations due to the growth and to the difference in size. Finally, the width of the different ambulacral and interambulacral areas at margin (WA), was performed measuring the distance between the interradial sutures of each area.

Plates were numbered according to Lovén (1872) system and interambulacral areas were shaded in grey. The systematic classification used, follows Kroh & Smith (2010).

Note

Since it is very rare that minute spines, pedicellaria, parts of the lantern or even the soft parts of the intestines conserve, the information which we consider useful for the classification of fossils will be searched in the structure of the test and, where possible, in the internal support. Moreover, even many tests of living clypeasteroids, because of the fast taphonomic processes they are subject, they come to us devoid of spines. In order to observe and compare the internal structures of some specimens examined, we also used specimens dissections and numerous x-rays in supero-inferior position.

Critical value of the Spearman rank correlation ro (α, n), with α = 0.05 and n = number of samples, are extract from the table of critical values obtained through the software SuppDist (Wheeler, 2005) implemented in R and based on the method of Kendall & Smith (1939).

OBSERVATIONS ON SAMPLES

SAMPLE 1

Echinodiscus cf. *auritus* Leske, 1778
Recent, Philippines (Plate 1 Figs. 1–8; Plate 2 Figs. 1–9; Figs. 2 a–d; Tables 1, 2).

EXAMINED MATERIAL. 5 specimens from Talibon in the north of the Bohol island, dredged at 50 m depth, code MAC.IVM 206 - 210, TL. 131 ÷ 154 mm; 5 specimens from Oslob, Cebu Island, MAC.IVM 211–215, TL 125 ÷ 173 mm; 2 specimens of generic provenance "Philippines" MAC.IVM81, 133; TL 150 and 152 mm.

GENERAL. In detail, the line of the ambitus is almost always polygonal, with almost rectilinear sections in correspondence of the different ambulacral and interambulacral areas. The line of the rear edge, with the two ambulacral notches, forms a "dovetail", which is always very irregular and sometimes is asymmetrical (Plate 1 Figs. 1, 2). In some cases, the "tail" protrudes from the ideal line of the ambitus, in other cases it does not arrive there because of its shortness; sometimes it is not straight and draws an arch that seems to continue the roundness of the rest of the ambitus. For this reason, it often happens that the two sides of each notch show a different length. The irregularities that occur along the margins, or even inside the notches, sometimes seem to be caused by attacks of predators, or by deformities present at birth, or by growth malformations. The test is very depressed (mean = 8% TL); the highest part of the test is located just before the apical disc which is eccentric forward, in a range that should be 54–58% TL. From a side-view, the profile is not uniformly tapered but, starting from the posterior margin, it goes up with a slight slope along the length of the notches, then it increases rapidly until just beyond the peak, from where it descends rapidly towards the anterior margin. The ambital

margin is thin and sharp rear (0.8 to 1.5 mm), and it becomes thicker more and more, as it gets closer to the front where the thickness varies from 2.5 to 3.5 mm. The adoral surface is flat or slightly plano-concave, with the inner point near the peristome; the last one is opened in a central position.

TEST STRUCTURE. In summary, the structure can be divided into two main parts: the central cavity, which houses most of the viscera, and the peripheral system that mechanically "supports" the whole test (Plate 2 Fig. 1). It is noted that the distribution of the interior supports (pillars, buttresses, "trabeculae") is not linked to the plates distribution, so they do not constitute the inner extension of their structure.

VISCERAL HOLLOW. This central cavity contains both the gut and the main vital parts (inner part of the respiratory organs, reproductive organs, etc.). In plan view, the shape is roughly rounded-polygonal, with the base line lying between the two rear ambulacra and located at right angled of the inter. 5. From the rear wall to the front, the length of the hollow corresponds to an average of ≈ 43% TL. From this cavity opens some pocket containing several vital organs, and two elongated cavities: one of these opens along the ambulacrum II and contains the caecum, while the other one, longer, contains the terminal intestines along the inter. 5 and leads into the periproct. L. Agassiz (1838–41) described in detail the path of the intestine compared to visceral hollow. From the aboral view the visceral cavity of these echinoids coincide with the width of the petalodium, whose PL ≈ 43% TL (Table 2). From the adoral side, instead, the visceral hollow is roughly contained into the limits of the first distal ambulacral post-basicoronal plates that are particularly extended, as you can see from the relative plating. The visceral hollow ceiling is supported by a system of 5 trabeculae that, from the lateral supports of the cavity (pillars and cellular tissue) run along the interambulacra, between the petals, until they join the reinforcement ring that supports the apical disc and the components connected to it (Plate 2 Fig. 2). The poriferous areas are flat, or in some cases slightly sunken. The Aristotle's lantern rests around the peristome, which opens at the center of the floor and has a sub-pentagonal outline. The auricles which support the lantern, flanked distally from navicular pits, stand on the basicoronal

interambulacral plates (Plate 2 Figs. 6d, 7a). The plank is formed mainly by post-basicoronal ambulacral plates; these ones are thin, measuring less than 1 mm thick, but they are reinforced by a "network" mesh structure more and more thick and dense as it gets closer to the side walls of the visceral hollow. Looking down the hollows, it is noted that the lantern covers most of the floor because it's relatively large in this population of echinoids. The lantern is "balanced" on the auricles, and it is moved by a system of ligaments attached to the perradial ambulacral sutures.

APICAL DISC. The apical disc is star-shaped with the points turned towards the interambulacra and is formed by a small madreporite (mean width = 5% TL), in which the 4 genital pores open. The genital and the ocular pores can be observed only on naked specimens (Plate 2 Fig. 3).

PERIPHERAL BALLAST SYSTEM. This system is formed by a sandwich composed by the oral and aboral parts of the test, each with its own combination of plates, and from an internal "cushion" formed by pillars or by buttresses of tissue with a cellular structure, crossed by more or less wide cavities. This "cushion" (with a probable coelomic origin) is formed by emi-structures that extend from the plates and are joined together in a plane more or less median (Plate 2 Figs. 4a, 6a). You note that the structure formed by radial ribs and microcanal that constitutes each plate, and which is evident after erosion, is the evidence of the direction of the growth of the same, which follows the distribution of the microchannels of the aquifer system and that isn't related to the direction of growth of the underlying internal structures. This complicated "sandwich" system constituted from plates, buttresses and trabeculae, reaches the ambitus where, in general, the last plate is "refolded" on itself in a peculiar way, forming precisely the margin. Counting the plates, in fact, you will sometimes consider that the last plate of a face is also the first one of the other face; only in some cases the two plates that delimit the upper and lower face appear to join up to the margin.

To illustrate this peripheral system of reinforcement, we also used simple radiological techniques, which show well the pillars, buttresses support and internal cavities distribution, and that is becoming a potential diagnostic tool (Plate 2 Fig.1).

AMBULACRAL AREAS. Along these areas opens the petals and the upper part of rear notches. The petals are closed, long twice their width and are sub-equal to each other (mean L5 = 23% TL, L7 = 19% and L9 = 20.5%). In 7 out of 12 specimens of this group, only one pair of post-basicoronal ambulacral plates occlude those of inter. 5; in the remaining specimens (MAC.IVM206; 207, 208, 209, 211, 212; 81) the inter. 5 is occluded by two pairs of post-basicoronal plates (Figs. 2b, c). The doubling of the post-basicoronal ambulacral plates in the ambulacra I and V, sometimes leads to a shifting of the position of the periproct towards the rear margin. In the ambulacra I and V, the width at the ambitus WA, is on average the 23% TL and the plates per column are 14-15; in the ambulacra II, III, IV, the WA are on average 37% TL but the plates are 12–13 in the ambulacra II and IV, while they are 13–14 on the ambulacrum III.

NOTCHES. The notches extend along the perradial sutures of the rear ambulacrum and they are opened in the posterior margin. Differences in shape and asymmetries observed in these notches, are common and therefore we have considered them as normal. The length of the notches (L1) in this sample varies from 18 to 27% TL (mean 23%). Because of the constant presence of deformations and/or malformations along the notches, the detection of L2 is not significant from a statistical standpoint. The notches are surrounded by 4 and 4 plates per column on the oral face and by 4–5 plates per column on the aboral one, approaching, therefore, to a 1/1 ratio (Fig. 2a–c). Between the petal tip and the corresponding notch there are 3–4 couples of plates, while, on the oral face the notches opens between the plates 4a/5b or 5a/4a. The ß angle is small and on average is almost 57° (Table 2).

INTERAMBULACRAL AREAS. The WA in interambulacra 1 and 4, is 40% TL and the plates per column are 14-15; in the interambulacra 2, 3, 5, however, the WA is on average 33% TL, while the plates per column are 15-16. The WA remains relatively constant, with the areas of the interambulacra 1 and 4 always larger than the other. The number of post basicoronal plates in inter. 5 is always 3 in column "a" and 3–4 in column "b".

PERIPROCT. The periproct is round (range 1.5–2, average 1.8% TL) and far from the rear margin (L11

= 14.5 ÷ 24.5% TL, average = 20%). Except a clearly abnormal specimen, the periproct always opens along the suture between the post-basicoronal plates 2b and 2a, that are partially paired (Figs. 2b, c).

FOOD GROOVES. The adoral face is crossed by very branched food grooves. Every single column in the ambulacral plates is traversed in the center by a main groove, which are joined to other numerous secondary thinner and less deep grooves (Fig. 2d). Other large grooves are joined to the main one at various levels: on the ambulacra I, II, IV and V these converge to the greater one in the middle of the corresponding ambulacral column; on the III, however, in several cases the secondary grooves converge closer to the stoma, within the post basicoronal area. Finally, the two main grooves of each column are joined exactly at the height of the tip of the basicoronal ambulacral plates, that then lead to the stoma. In the rear ambulacra they run along both sides of the notches. The ambulacral plates crossed by food grooves have a greater deflection near of the stoma.

PERISTOME AND ARISTOTLE'S LANTERN. The peristome varies from rounded to sub-pentagonal shape and is relatively small (mean = 3% TL). The basicoronal circlet is small (mean L13 = 11% TL). The basicoronal interambulacral plates are quite regular and always are disjointed from the corresponding post-basicoronal ones. The Aristotle's lantern is very flat and especially developed in width, and it is formed by five jaws delta-wing shaped, whose bisector is a groove within where the teeth run horizontally. The teeth are knife shaped, with the sharp end facing toward the stoma (Plate 2, Figs. 5, 8); Always along the bisector near the stoma, a small fork and the corresponding navicular dimples that fit in the underlying auricle are located in each jaw. The jaws are held together by ligaments attached to perradial ambulacral sutures. We verified if there was a direct relationship between the size of the lantern and the size of its basicoronal circlet. In the specimen of Bohol, MAC.IVM209 (TL = 152 mm) the size of the basicoronal circlet (L13) is 11.5% TL; the height of the pentagon formed by the Aristotle's lantern, as in the plating, measures ≈ 40 mm, equal to 26.3% TL; the distance between the support of the inter. 5 and the edge of the stoma is of ≈ 6.5 mm and the diameter of the stoma exceeds 3.5 mm.
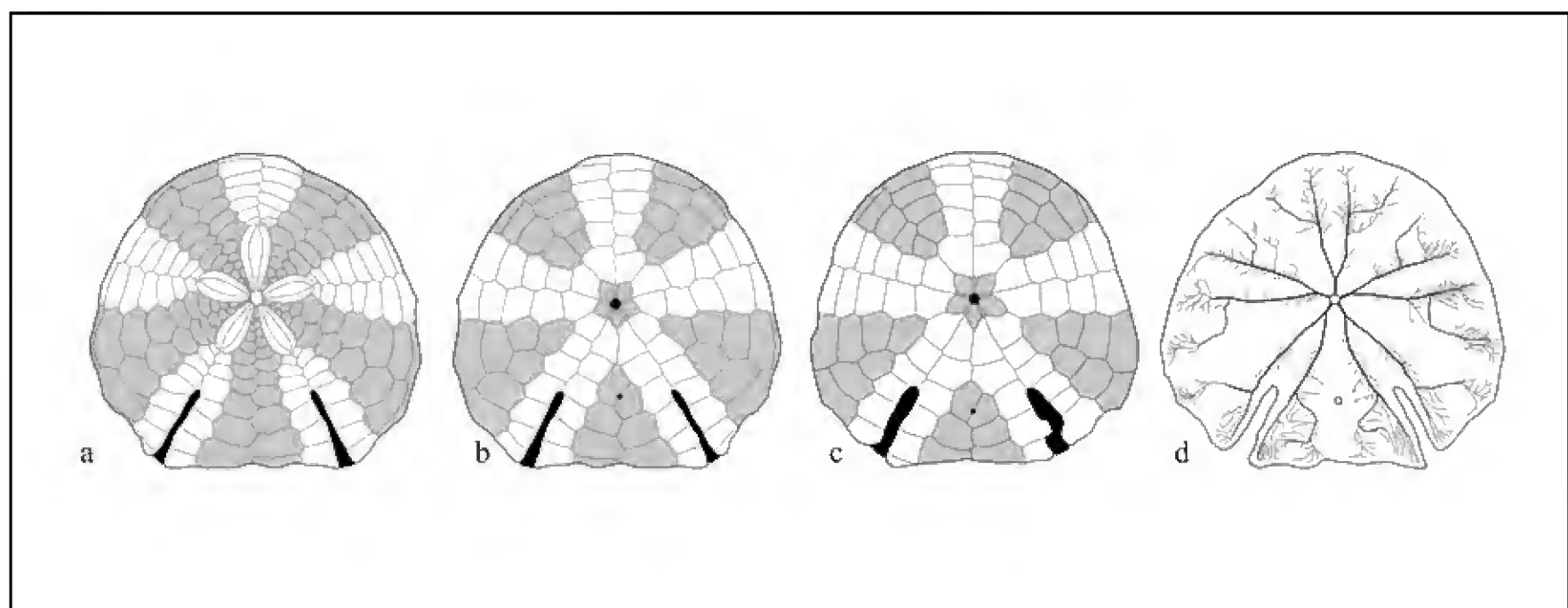
Fig. 2: "*Echinodiscus*" cf. *auritus*, Recent, Philippines: a, b) respectively, aboral and oral plate structure of MAC.IVM 210; c) oral plate structure of MAC.IVM 211: d: food grooves.

Specimen	TL	TW	TH	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	øPc	øSto
IVM215	173	103	7.5	21.5	2	13.5	57	22	11.5	18	10	20	9.5	21.5	31	11	1.8	3
IVM208	131	104	7.4	26	2	17	55	20	10	16.5	9.5	17	8	20	33	10	1.5	2.8
IVM210	141	104	7.4	27	1.5	14	54	22	10	17.5	9	19	8.5	22.5	28.5	10.5	1.8	2.5
IVM206	148	103.5	7.4	25	2	11.5	55	21	9	18	9	18.5	8	24.5	28	9.5	1.5	2.5
IVM209	152	106.5	9.2	22.5	2.5	15.5	56	24.5	12	18.5	11	20	10	20	31	11.5	2	2.8
IVM081	152	102	7.5	20	2	12.5	54	27	10	22.5	10	23	9	14.5	35	11.5	1.6	3
IVM213	152	106	8.5	23	3	12.5	56.5	24.5	12.5	19	11.5	21.5	10.5	22	30.5	12.5	2	3.5
IVM207	154	101	8	18	2.5	15	56	22.5	11	20.5	10.5	22	10	17.5	32	11.5	1.8	2.5
IVM214	156	108	9	25	3	12	58	23	13.5	21	13	22	12.5	21	31.5	11.5	2	3.2
IVM212	157	103	9	22.5	3.5	10	56	26	13.5	20	12.5	20.5	11	20	31.5	12	2	3.5
IVM211	159	105	8	24	4.5	14	57	23	11.5	20	10	22	9.5	16.5	35	11.5	1.6	3.5
Range		101 - 108	7.4 - 9.2	18 - 27	1.5 - 4.5	10.0 - 17.0	54 - 58	20 - 27	9.0 - 13.5	16.5 - 22.5	9.0 - 12.5	17.0 - 23.0	8.0 - 12.5	16.5 - 24.5	28.0 - 35.0	9.5 - 12.5	1.5 - 2	2.5 - 3.5
Mean		104	8	23	2.5	13	56	23	11	19	10.5	20.5	10	20	31.5	11	1.8	3
Variance		7		9	3	7	4	7	4.5	6	3.5	6	4.5	8	7	3	0.5	1
Range-V		4.7		39	120	54	7	30	41	31.5	33	29	45	40	22	27	28	33

Table 1. Morphometric data of "*Echinodiscus*" cf. *auritus* (Philippines, Recent). TL in mm, other data in % TL.
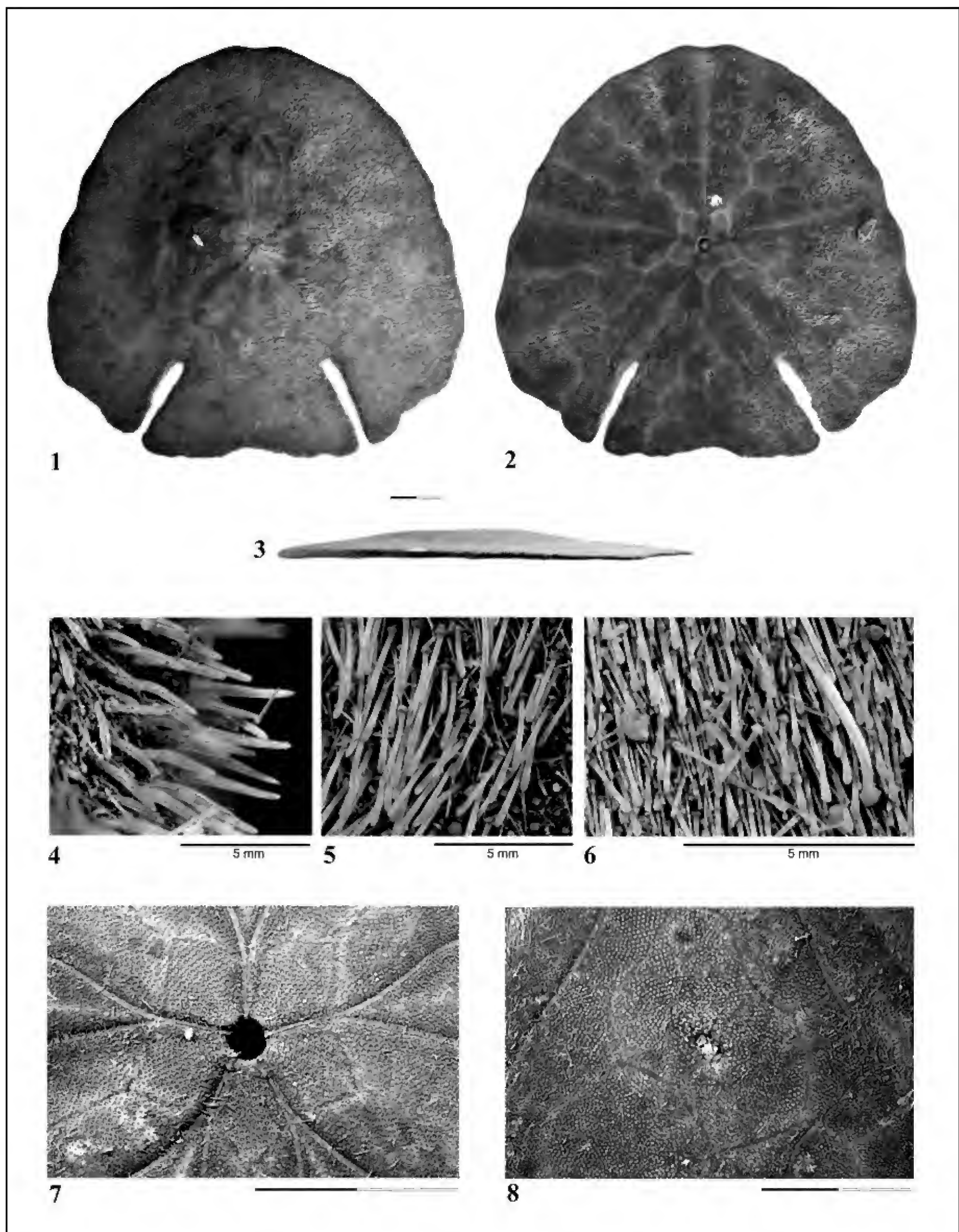
Plate 1: *Echinodiscus* cf. *auritus* from Philippines (Recent): external features. Figures 1, 2, 3. Aboral, adoral and lateral views of MAC.IVM 212. Figure 4. Close up view of the pointed spines on the inner slits surface. Figure 5. Primary and secondary aboral spines. Figure 6. Claviform primary and secondary aboral spines. Figure 7. Tuberculation and food grooves of the peristomial area. Figure 8. Periproct, tuberculation and food grooves on posterior areas.
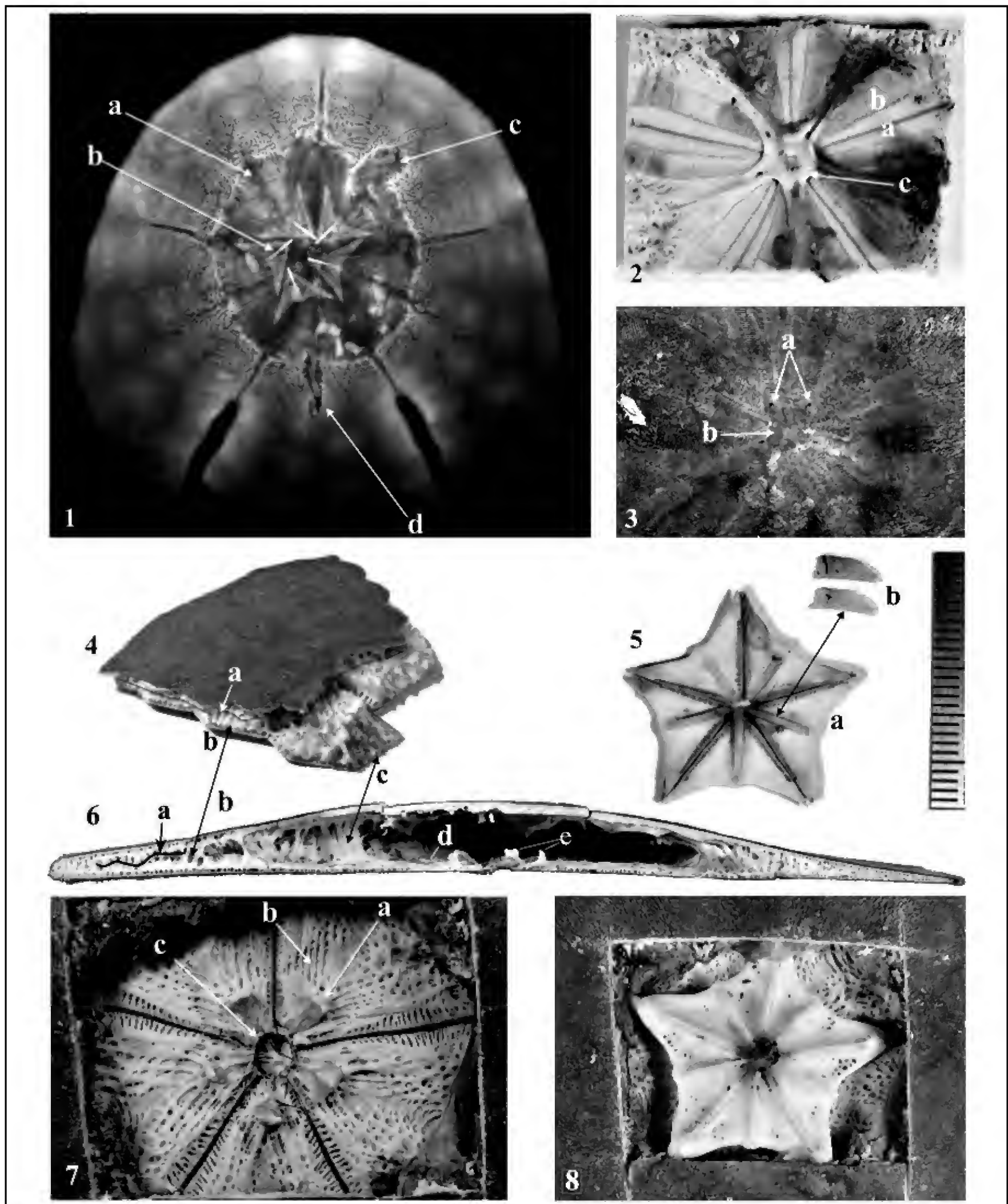
Plate 2. *Echinodiscus* cf. *auritus* from Philippines (Recent): internal features. Figure 1. Radiograph of specimen MAC.IVM 215 (Dap = 173 mm): a) central hollow; b) teeth on wing of disarticulated lantern; c) caecum cavity; d) terminal intestine cavity. Figure 2. Internal view of ceiling of central hollow: a) interporiferous areas; b) poriferous areas; c) apical disk reinforcement. Figure 3. Corresponding external view of apical disc: a) genital pores; b) madreporite. Figure 4. Fragment of the test with: a) separation surface of internal structures; b) peripheral pillar and buttresses; c) walls delimiting the central hollow. Figure 5. Aristotle's lantern of MAC.IVM 209, upper view: a) jaw; b) teeth. Figure 6. MAC.IVM 209: antero-posterior section (from the left to the right); a) separation surface of internal structures; b) peripheral pillar and buttresses; c) walls delimiting the central hollow; d) floor of the central hollow; e) lantern supports. Figure 7. a) lantern support; b) rib in a network of floor reinforcement; c) peristoma. Figure 8. MAC.IVM 209: Aristotle's lantern in position.

In the specimens MAC.IVM81, with the same length as the previous one, L13 is ≈ 12% TL; the height of the pentagon of Aristotle's lantern measures 38 mm, equal to 25 % TL; the distance between the support of the interambulacrum 5 and the stoma is 7 mm, equal to 4.6% TL, while the diameter of the stoma is 3 mm. In the specimen MAC.IVM206 (TL = 148 mm), the lantern measures 30 mm, which corresponds to ≈ 20% of the TL. So the size of Aristotle's lantern varies, in the specimens tested, around 20-26% TL and does not seem related to the width of the basicoronal circlet (L13). The basicoronal interambulacral plates are flat and studded with large tubercles crenulated and perforated. The spines that surround the stoma, post-mortem, are inclined to cover it completely.

TUBERCULATION AND SPINES. In the oral face the tuberculation is dense, consisting of primary tubercles medium sized, poorly differentiated and extended over the face, and secondary tubercles that form a granulation background, scarcely distinguishable. The tubercles are larger around the periproct and the smaller sized ones are found particularly along the main food groves (Plate 1 Figs. 7, 8). In the aboral face the tubercolation is undifferentiated, thick and petite, evenly distributed over the entire surface.

The spines are well differentiated according to the areas in which they are located, the larger are surrounded by numerous small ones, that are also much thinner. Both types are more or less cylindrical, slightly thinner distally, and traversed by numerous thin longitudinal ribs, and both end with a rounded tip (Plate 1 Figs. 4–6). Spines of medium and large size are found around the stoma; other ones with a medium-length cover ambulacral center areas, including the entire length of the notches, even on the inner surfaces; other spines, much shorter and thinner and with a hinted club-shaped, however, cover the areas around the food grooves. Along the ambitus and along the notches there are often curved and sharp spines. Also, together spines of medium length, cylindrical and with pointed termination, there are stubby, short and clearly club-shaped spines. Even all the aboral face is covered from thickly spines, generally smaller than those already described. Apart the surfaces of the petals, where the spines are cylindrical and pointed, and near of the notches, there are transitions forms of spines between

Specimen	TL	Apical disc	PL	WA	ß
IVM206	148	4.5	41	33	61
IVM207	154	4.5	43	30	58
IVM208	131	5	40	37	57
IVM209	152	5.5	45	37	54
IVM210	141	5	41	33	55
IVM211	159	4	45	30	56
IVM212	157	4	48	32	56
IVM213	152	4	45	34	57
IVM214	156	5	43	34	59
IVM215	173	4.5	43	34	55
Mean		4.6	43.4	33.4	57
Range		4-5.5	41-48	30-38	54-61

Table 2. Morphometric data of apical disc, PL, WA and ß, in "*Echinodiscus*" cf. *auritus* (Philippines, Recent). TL in mm, ß in degree, other data in % TL.

those of the adoral face and those of the aboral one, while all the other spines have club-shaped with the ends decidedly thickest of the rest of the stem (Plate 1 Fig. 6).

SAMPLE 2

Echinodiscus **cf.** *auritus* Leske, 1778
Recent, Madagascar (Plate 3 Figs. 1–7; Plate 4 Figs. 1–7; Figs. 3a–c; Tables 3–7)

EXAMINED MATERIAL. 32 specimens from Mangili, Province of Tulear, caught in back-barrier lagoon, ≈ 5 to 8 m deep, MAC.IVM82 - 113, TL = 74 ÷ 140 mm.

GENERAL. The ambital line is almost polygonal; the posterior margin line, sited between the two notches (the tail), is always irregular and often very asymmetric. Although in smaller individuals seem to prevail lines with a rounded shape, the larger individuals present clearly truncate lines.

As in the specimens coming from Philippines, in some cases the "tail" comes out from the ideal rounded line in the ambitus (Plate 3 Figs. 1, 2). The test is medium - large (max TL = 140 mm), with a consistent variability of the relationship TL/TW, and very depressed (mean TH = 8% TL). The highest part of the test is located at the apical disc that is forward eccentric (mean L4 = 55% TL). The side profile is slightly and almost uniformly sub-conical. Starting from the posterior margin, it rises almost uniformly and then decreases as the inclination, finding the maximum in an area that has the apical disc in the center. This trend is repeated to the anterior margin, just a little steeper (Plate 3 Fig. 3). Only on some larger specimens the line of the rear profile rises more gently towards the top and remained low over the "tail" of the echinoid. On the specimen MAC.IVM111 (TL = 140 mm), the ambitus is thin and sharp posteriorly (0.8 mm), but it thickens more and more as it gets closer to the front, where the margin is often ≈ 2.5 mm and rounded. The adoral surface is flat or slightly plano-concave, with the inner point near the peristome; the last one opens in a central position (L11+L12 mean = 50% TL). The periproct is far from the posterior margin (L11 = 17 to 23.5 % TL). Especially in larger specimens there are showy deformations, due to both growth malformations, or to damage from predations. Many of these damages from predation are self-repaired in life, since they are covered with new tubercles.

TEST STRUCTURE. The structure of the test of these echinoids is not very different from that of the specimens coming from the Philippines; this structure can then be divided into two main parts: the central one, which contains visceral cavity, and the peripheral one, which contains the pillars and buttresses made of cellular structure (Plate 4 Figs. 1, 4).

VISCERAL HOLLOW. On the specimen MAC.IVM111, this cavity has a rounded to sub-pentagonal plan, with the base placed between the rear ambulacra and right-angled to the interambulacrum 5; the distance between the extreme rear and the front of the hollow is approximately 38% TL. In general, from an upper view the echinoid present the visceral hollow circumscribed into the petalodium (mean PL = 40), while the floor ends

before the distal limit of the first post-basicoronal ambulacral plates. The ceiling structure of the visceral hollow is comparable to that of the specimens coming from Philippines; the surface of the interporiferous areas are raised, while that the poriferous ones are flat or very slightly concave. Unlike the specimens coming from the Philippines, the relationship between basicoronal and post-basicoronal plates is very changeable even in the same specimen itself. This population shows a high variability in the development of the basicoronal interambulacral and the post-basicoronal ambulacral, while the development of the other plates is normal (Plate 5 Figs. 3–5).

APICAL DISC. the small apical disc (about 5.5% TL) is formed by the star shaped madreporite, and presents 4 genital and 5 ocular pores (Plate 3 Fig. 4). All the specimens are adult and present all the 4 genital pores open.

PERIPHERAL BALLAST SYSTEM. Also for the structure of the visceral hollow, there are no fundamental differences compared to those of the specimens coming from Philippines. The ribs, the pillars and the reinforcing buttresses seem more delicate than the ones of the Philippine specimens (Plate 4 Figs. 4–5).

AMBULACRAL AREAS. The petals are sub-equal, long about twice of their width and always closed, but the overall shape varies also conspicuously (mean L5 = 21%; L7 = 19%; L9 = 18.5% TL). There are interporiferous areas wide 1.2 to 2 times than the poriferous ones.

Given the numerical strength and the size range of this group of echinoids, we detected changes in petals size in relation to the size of the test (see Table 4). In all the specimens of this group, only a pair of post-basicoronal ambulacral plates occlude those of the interambulacrum 5 in the oral face. Unlike the Philippine sample, in this one the relationship between the basicoronal and post-basicoronal interambulacral plates is highly variable, with also several joint plates in the same specimen (table 5). In the ambulacra I and V, the WA is on average the 23% of TL and the plates per column are 14-15; in the ambulacra II, III and IV, WA is on average the 37% TL, while the plates per column are 12-13 in the II and IV, and 13-14 in the ambulacrum III.

REAR NOTCHES. There is a high frequency of malformations and deviations in the population, due either of delayed or unfinished processes of disjunction, occurred perhaps in the course of the individual development. In specimens MAC.IVM108, 111 and 112, the two long edges of the notches have not completed the disjunction, in other cases the notches are very malformed. Often they are also very asymmetric, so the two notches are quite different in the same individual. In this group of echinoids the disjunction of lunules interests 4–5 couples of plates on the oral face and 4–5 on the aboral ones, with a 1/1 ratio. Between the petal tips and the beginning of the notches there are 4 or 5 plates per column, in the oral face the notches opens between post-basicoronal plates 3a/3b. ß range from 49° to 62° for an average of 55° (Table 6).

INTERAMBULACRAL AREAS. The WA of the interambulacra 2, 3, 5 measures on average the 32% TL; on the interambulacra 1, 4, however, measures on average the 40% TL. The number of plates in the ambulacra 1 and 4 are 14-16, such as in the interambulacra 2 and 3, while on the inter. 5 they are 13-14. In the oral face the inter. 5 is always occluded and it has always 4 and 3 post- basicoronal plates per column.

PERIPROCT. The periproct is small, because in young specimens it is the 2.6% while is about the 2% TL in the larger ones. L11 is less variable than in the sample coming from the Philippines, but the average of L11 is always ≈ 21% TL. In almost all the specimens (31 of 33) the periproct opens between the plates 2/2b in the inter. 5; only in two specimens it is at the end of said suture, in position 2a/2b/3a (Table 5).

FOOD GROOVES. The food grooves in this sample do not differ much from those coming from the Philippines, only in some specimens, the two grooves of each ambulacral column join together a little before the tip of the basicoronal plates (Fig. 3c).

PERISTOMA, ARISTOTLE'S LANTERN AND BASICORONAL CIRCLET. In this group of echinoids the peristoma is circular, with a diameter ranging from 4 mm on smaller samples, up to 3 mm of the larger ones (overall average 3.5%TL). The basicoronal circlet is small (mean L13 = 11.5% TL). The basicoronal interambulacral plates are completely irregular, with considerable variations in length and shape, which can diversify from triangular to lanceolate and very elongated. Often, even in the same individual, there are some post-basicoronal plates in contact and other disjointed; also, the second interambulacral plates, disjointed or not, can be found both in meridoplacous or amphiplacous condition (see Table 5). The Aristotle's lantern supports stand, on the floor of the visceral hollow of the basicoronal interambulacral plates (Plate 4 Figs. 4, 6) ; given that the length of the plates varies greatly, we observed that the relative position of the supports is independent. In the specimen MAC. IVM112 (TL = 140 mm) the pentagon formed by the lantern measures 15.3% TL, absolutely far from the 20.2% of the TL detected in the sample MAC.IVM206 (TL = 148 mm) coming from the Philippines. In another sample of TL = 116 mm, the lantern measures about 15% TL.

From what has been observed, it is clear that the abnormal length of the basicoronal interambulacral plates does not seem to lead to consequent structural changes.

TUBERCULATION AND SPINES. On the oral face the tuberculation is dense, consisting of medium sized tubercles, poorly differentiated and extended over the entire surface. The tubercles are larger around the periproct (Plate 3, Figs. 5–7) and the smaller ones are found particularly along the main food grooves. On the aboral face the tubercolation is undifferentiated, thick and petite, evenly distributed over the entire surface.

The echinoids of this sample are devoid of spines, except in some restricted areas, such as the edges of the stoma and the inner surfaces of the notches. The spines that we have observed are not dissimilar to those observed in the Philippine sample.

DISCUSSION

One of the problems that has arisen in the parallel work done by Stara & Borghi (2014), was the evidence of a marked decrease in the number of plates and a reduction in the internal structure, during the geological time.

It is shown, therefore, the need to count all the plates of echinoids we examined (Table 7) subjecting the obtained data to a statistical examination.
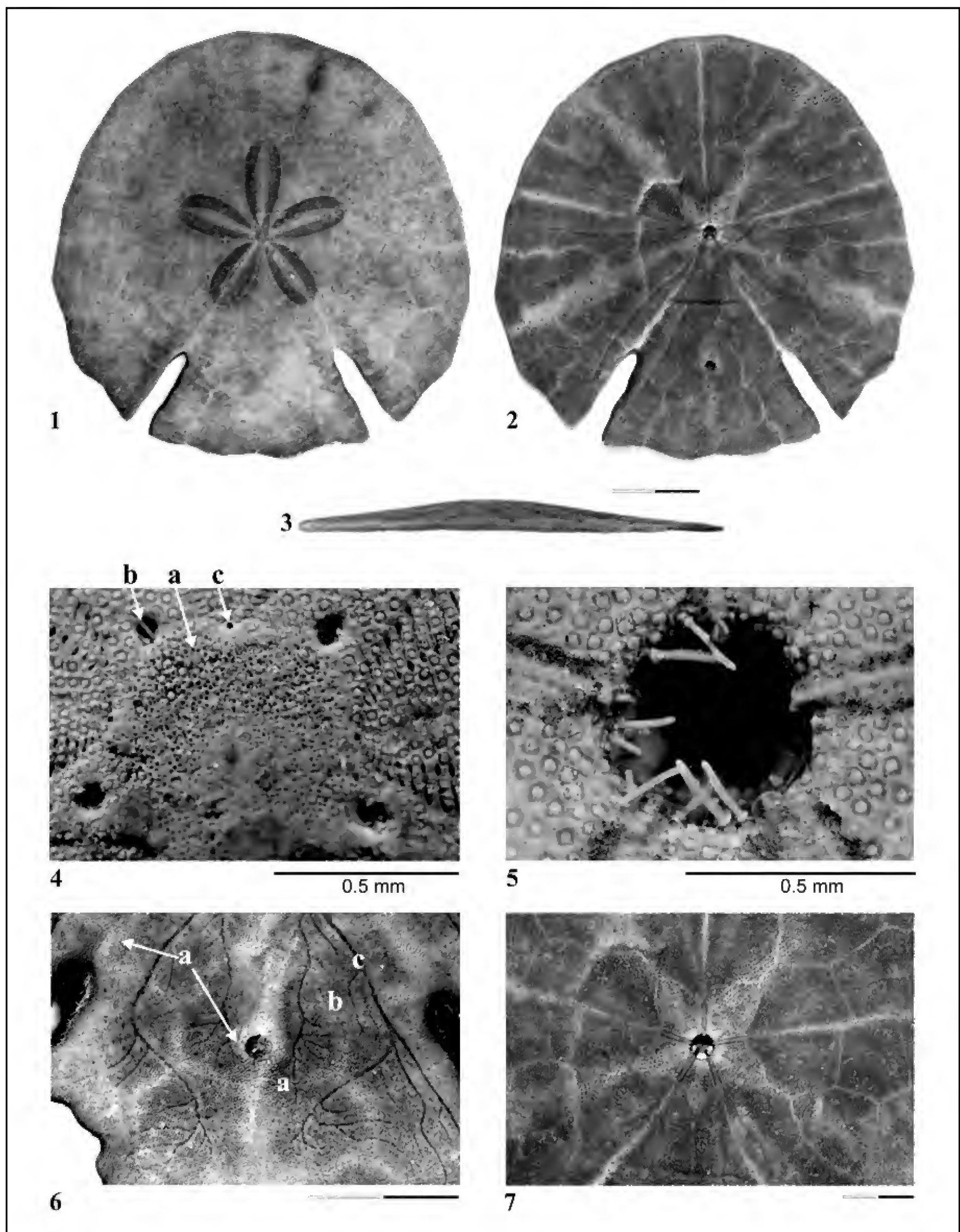
Plate 3. *Echinodiscus* cf. *auritus* from Mangili, Madagascar (recent): external features. Figures 1, 2, 3. Aboral, oral and lateral views of MAC.IVM 81. Figure 4. View of the apical disc with madreporite (a), genital (b) and ocular (c) pores. Figure 5. Stoma surrounded by medium sized tubercles and small spines. Figure 6. Large (a) and small (b) primary tubercles; (c) strongly articulated food grooves in MAC.IVM 110. Figure 7. Close up of the peristoma, disjoint basicoronals and scarcely differentiated tuberculation in MAC.IVM81.
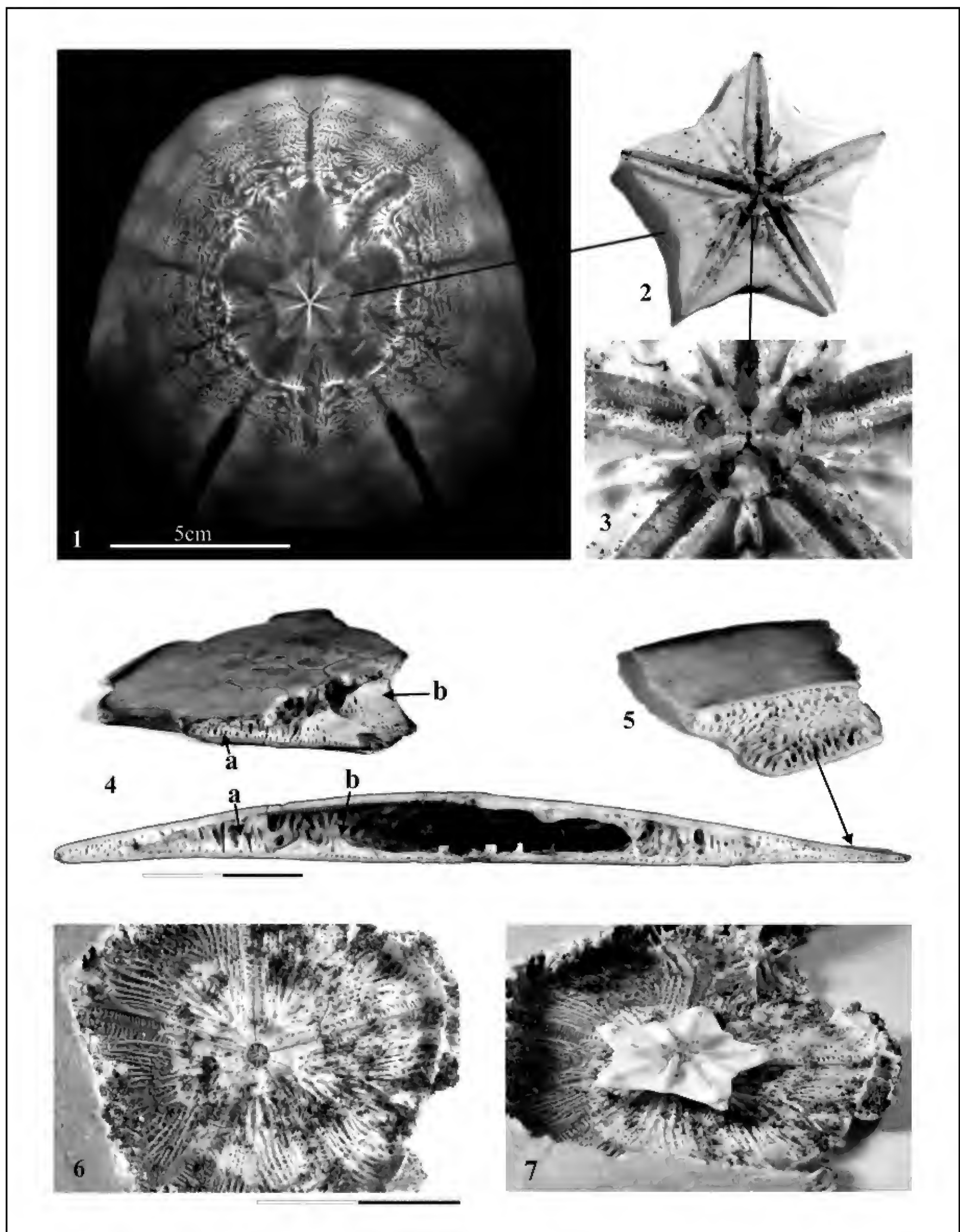
Plate 4. *Echinodiscus* cf. *auritus* from Mangili, Madagascar (Recent), internal features. Figure 1. Radiograph of MAC.IVM 109 (Dap = 125 mm). Figure 2. Aristotle's lantern, oral view. Figure 3. Close up of the support system and teeth. Figure 4. Fragment and antero-posterior test section of MAC.IVM 103 with: a) peripheral pillar and buttresses; b) walls delimiting the central hollow. Figure 5. Close-up of supports into the last aboral and adoral plates. Figure 6. Floor of the central hollow with ribs in a network of reinforcement. Figure 7. Small Aristotle's lantern in position.
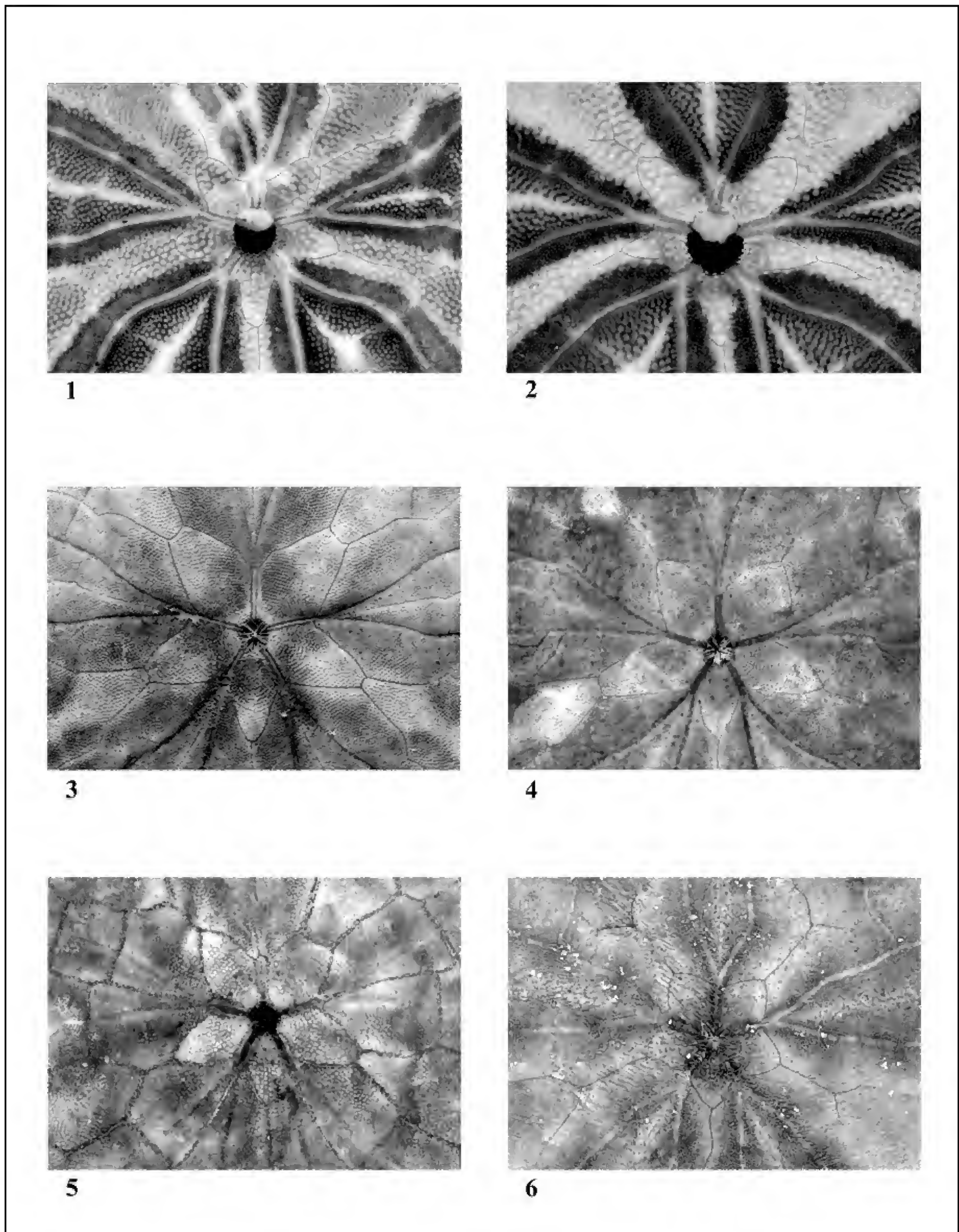
Plate 5. *Echinodiscus* cf. *auritus*. Instability of the disjunction in basicoronal interambulacral plates in"*Echinodiscus*" speci-mens. Figures 1, 2. *E. bisperforatus* (South Africa, Recent): 1) interambulacra 2, 3 continuous; 1, 4 and 5 disjunct; 2) all plates disjunct. Figures 3, 4, 5. *E.* cf. *auritus* (Mangili, Madagascar, Recent), MAC.IVM110: interambulacra 1, 2, 3, 4 continuous; 5 disjunct; MAC.IVM115 interambulacra 1, 2, 3, 5 disjunct, 4 continuous; MAC.IVM84 interambulacra 1, 2 continuous; 3, 4, 5 disjunct. Figure 6. *E.* cf. *auritus* (Philippines, Recent), MAC.IVM206: interambulacra 1, 2, 3, 4 disjunct.
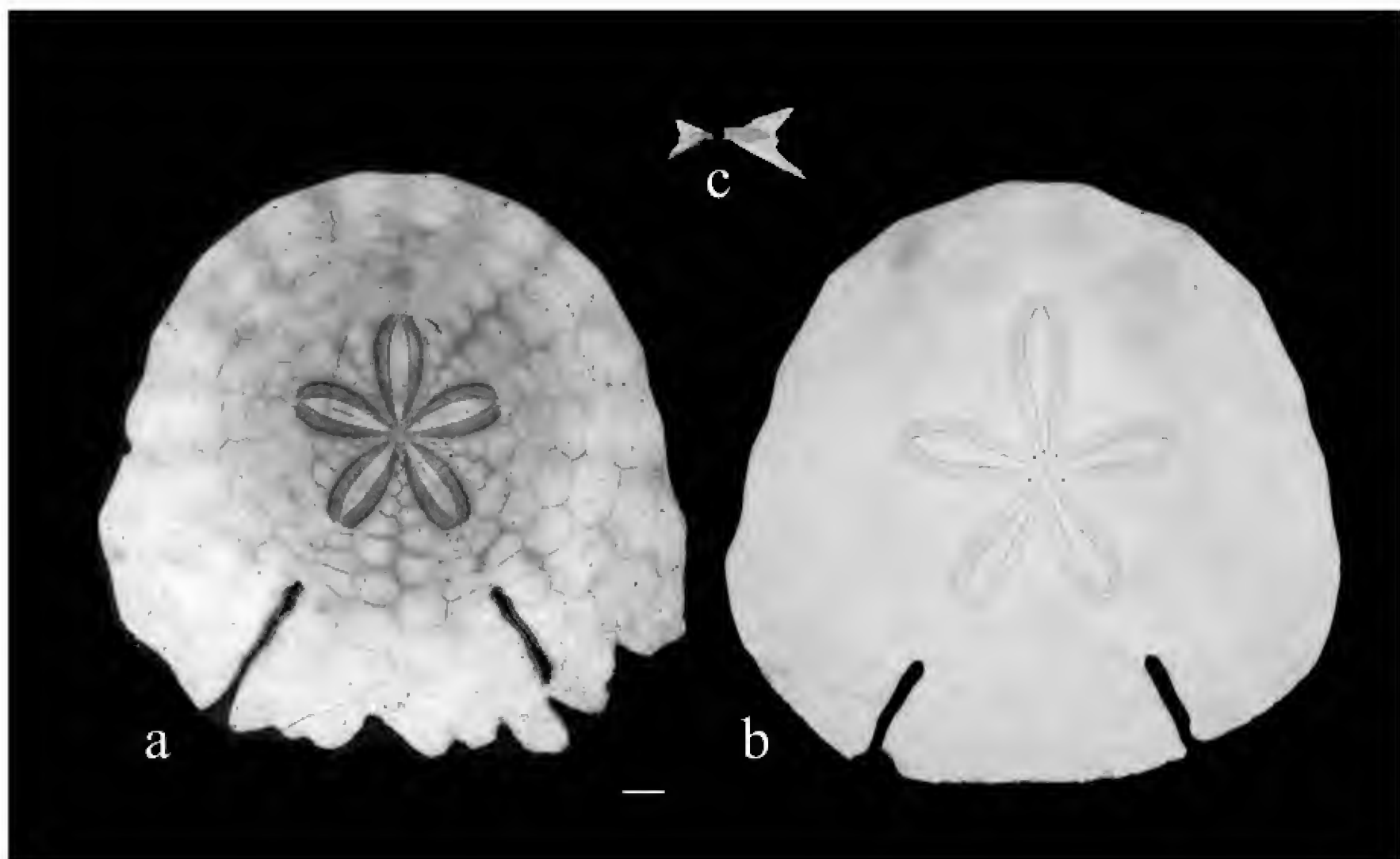
Plate 6. Comparison of Aristotle's lantern of "*Echinodiscus*" cf. *auritus* in specimens from a) Mangili; b) Philippines; c) jaws.

This has documented, as expected, given the preliminary data (Table 3) that in our sample of adult individuals, while doubling the size, the number of plates per column in some interambulacra and ambulacra does not vary significantly (see Figure 4 and conclusions).

This confirms the fact that the reduction of plate numbers observed in geologically younger specimens is credible. Moreover, even Durham (1955) cites a case like this, with a decrease of plates observed in *Echinocardium* from subsequent geological periods.

With regard to the statistical analysis, however, the samples analyzed show a distribution of length (TL) that goes from a minimum of 54 mm to a maximum of 151.5 mm (mean 104.5); standard deviation 20.7; range 77.5; median 103.3 (see Fig. 4, Length Frequency Distribution).

For each sample were also collected the counts related to the number of plates present in the various ambulacral and interambulacral column. Analyzed here are those related to oral and aboral face of the interambulacrum 5 (defined respectively 5 - oral and 5 - aboral) and those of the single-sided aboral (3-aboral) of the III ambulacrum. To assess the in-dependence of these measures in relation to TL, we test by "Spearman ρs" the null hypothesis H0: $\rho s =$ 0 ("no correlation") for each of the following pairs of variables, considered separately: TL – 5 - oral; TL – 5 - aboral, TL – III aboral. The level of significance chosen is $\alpha < 0.05$.

Scatter plots obtained for each pair of variables do not seem to show any linear relation between the variables represented. This seems also suggested by the test of Spearman (ρs), which does not allow us to reject the null hypothesis ("no correlation") with a 95% confidence level, as reported in Table 8.

We have not considered necessary, because evident, to verify statistically the variation in the size of the back notches in this sample, which is relatively low. In fact, in a lot of sizes ranging from 21 to 28% TL (mean 24%), we observed a variation of 29% on average value).

Another goal of this work was to try to understand the real extent of variability in L1, PL, L11, WA and ß.

The variability of L1 is significant and similar in both samples (20–28%, mean 23% TL, against L1 21–28%, mean 24% TL), but does not seem to affect the possibility of specific distinction.

Specimen	TL	TW	TH	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	øPc	øSto
IVM82	74	101	5.5	22.5	3.5	13	54.5	20.5	8.5	19	9	18.5	8.5	24	27	13	2.5	4
IVM83	76	100	6	24	2.5	13	54.5	19.5	8	17.5	8.5	17.5	7.5	21	27.5	11.5	2.5	4
IVM84	79	102	7.5	24.5	3.5	12.5	53.5	19.5	8.5	18	9	18	8.5	19	30	11.5	3	4
IVM85	79	98	6	22	3	14	55	21.5	8	17.5	8.5	17.5	8	17	33	10.5	3.5	4
IVM86	82	102	8	23	3	12.5	53.5	21.5	9	18.5	9	18	8.5	21.5	27.5	11.5	3	4
IVM87	82	102	7	23	3.5	15	55	21	8.5	17.5	9	18	8	23	26.5	11.5	2.5	3.6
IVM88	82	103	6.5	23	2	12	55	19.5	7.5	17	8	16.5	7.5	22.5	27.5	11.5	2	4
IVM89	88	98	7	23	3	14	55	20	8.5	18.5	9	18	8.5	22	28.5	11.5	2.5	4
IVM90	88	103	7.5	25	3	13	55	20.5	8.5	18.5	8.5	18	8.5	19	30.5	12.5	2.5	3.5
IVM91	88	99	8	21.5	3	14.5	55	21.5	9.5	18.5	9	18.5	8	18.5	32	12.5	3	4
IVM92	93	97.5	8.5	23.5	2.5	12.5	56	22.5	9	21	10.5	19.5	7.5	22.5	28	11	2.2	4
IVM93	94	99	8	23.5	2.5	13.5	55	22.5	8.5	19	9	19	8	21	28.5	10.5	2.5	4
IVM94	96	101	7	24.5	2.5	13	54	21.5	8	18.5	8	17.5	7.5	22	27.5	10	2.5	3.5
IVM95	97	99	7	21.5	4	15	55	21	7.5	18	9	17.5	8	21.5	30	11	2.5	3.5
IVM96	98	100	7.5	27.5	2	12	55	21.5	9	17	9	18	9	25	26.5	11.5	2.2	3.5
IVM97	103	97	8.5	24	2.5	13	55	22.5	10	18.5	10	20	10	24	27	11	2	4
IVM98	104	102	8	25	5	14	54	21.5	10	18.5	10	17.5	9.5	18	33	11.5	2.2	3.5
IVM99	108	98	9	25	3.5	15	56	20.5	9	17.5	11	17	9.5	22	28	11.5	2	3.5
IVM100	108	102	9.5	27	2	12.5	55	20.5	8	19	8	19	8	22.5	27.5	11.5	2.5	3.3
IVM101	111	95.5	9	21	1.5	13	56	20.5	10	19	9.5	20	9	20.5	29	12	2.2	3.2
IVM102	112	100	7	23	2.5	12.5	55	21.5	9.5	18.5	8.5	19	8.5	19	30.5	12.5	2.5	3.5
IVM103	114	99	9	25	2.5	12.5	56	22	10.5	21	11	19.5	11	21	31	11.5	2.2	3.5
IVM104	118	100	9	26	2	15.5	55	22	9	20.5	9.5	18.5	8.5	19.5	29.5	11.5	1.8	3.5
IVM105	119	102	9	21	2	13.5	55.5	22	10	18.5	10	19	9.5	19	30.5	12	1.8	3.5
IVM106	120	98	9	23	1	16.5	56.5	20	8.5	16.5	8.5	17.5	8	20	29	11.5	2.2	3.5
IVM107	121	100	9	24.5	1	14	55	20	8.5	19	8	18.5	10	23.5	28.2	11.5	2.2	3
IVM108	121	102	9	23	1.5	14	56	21	8	18	8.5	18.5	8	24	28.3	11.5	2.2	3.2
IVM109	125	99	9.5	24	2	12.5	55	21	8	18.5	8.5	19	8.5	20	30	11.5	2	3
IVM110	135	106	12	25.5	2	11.5	55	23	8.5	21	10	21.5	9.5	18.5	31.5	10.5	2	3
IVM111	132	100	10	27.5	0.5	12.5	57	20	8.5	18	9	17.5	8	22.2	30.2	11.8	2	2.5
IVM112	140	105	12.5	26	1.5	12	56	23.5	10	21	10	22	9.5	18.5	32	11.5	2.2	2.5
IVM113	126	101	10	28	1.8	11.5	54	22.5	9.5	19.5	9.5	19	9	19.5	30	12	2	4
Range		95.5-106	5.5-12.5	21-28	1-5	11.5-16.5	53.5-56.5	19.5-23.5	7.5-10.5	16.5-21	8-10.5	17-22	7.5-10	18-24	26.5-33	10-13	1.8-3.5	2.5-4
Mean		100.3	8.3	24	2.1	13.2	55	21.18	8.8	18.6	9.1	19.5	8	20.9	29.2	11.5	2.3	3.5
Variance		10.5	7	7	4	5	3	4	3	4.5	1.5	5	2.5	6	6.5	3	1.7	1.5
Range - V		10.4	84.3	29.1	190.4	37.8	5.4	18.8		24.1		25.6		28.7	22.2	26	73.9	42.8

Table 3. Morphometric data in "*Echinodiscus*" cf. *auritus*, Recent, from Mangili, Tulear, Madagascar.
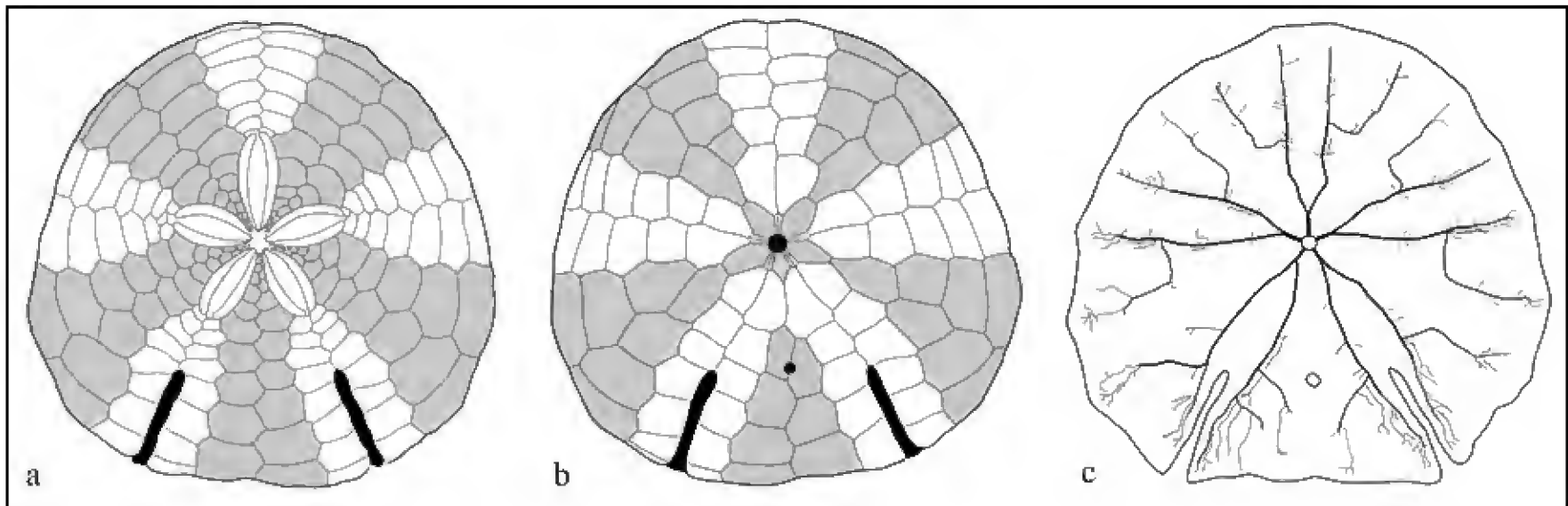
Figure 3. *Echinodiscus"* cf. *auritus* from Mangili, Tulear, Madagascar (Recent): a, b) respectively, aboral and oral plate structure of MAC.IVM 87; c) food grooves.
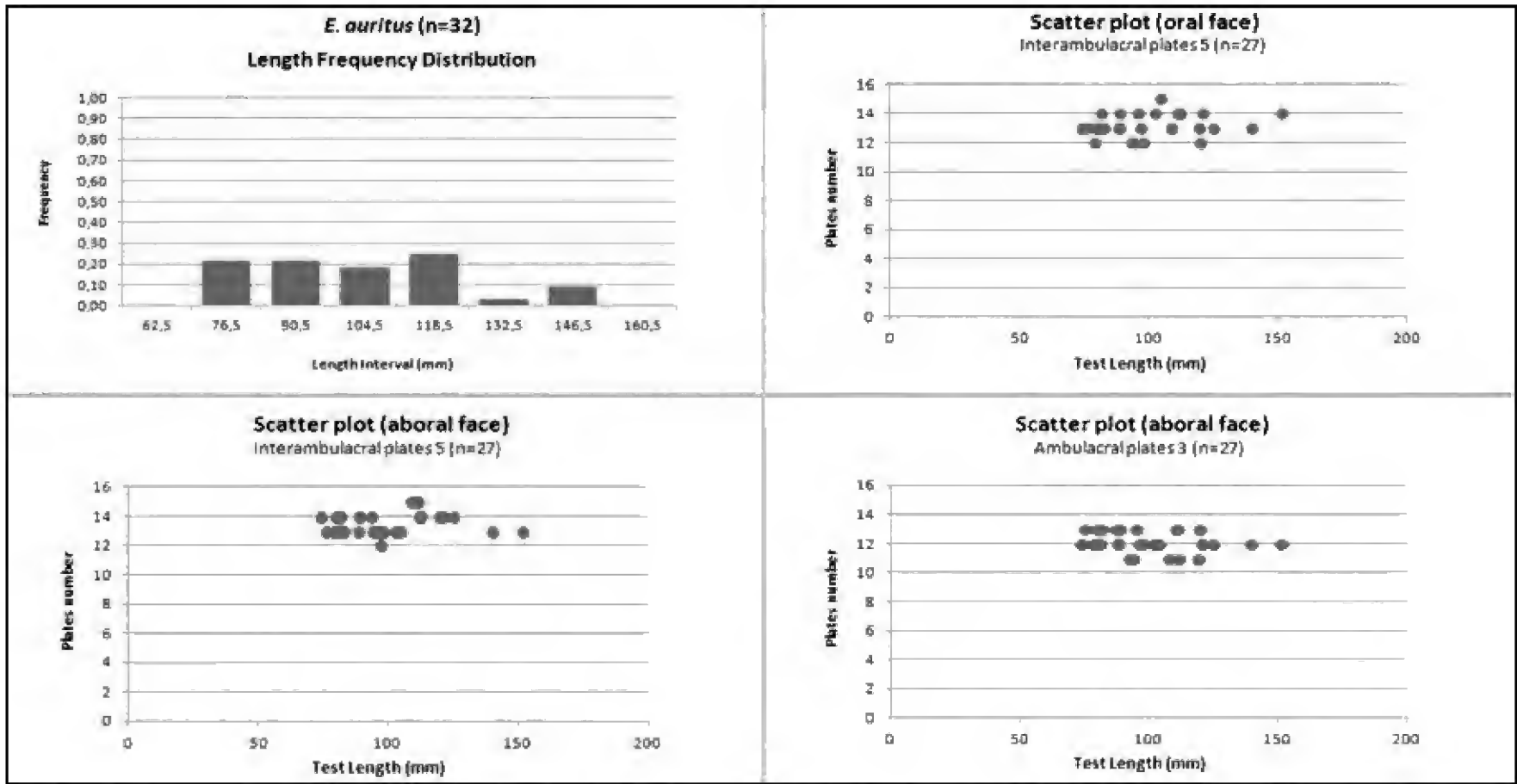

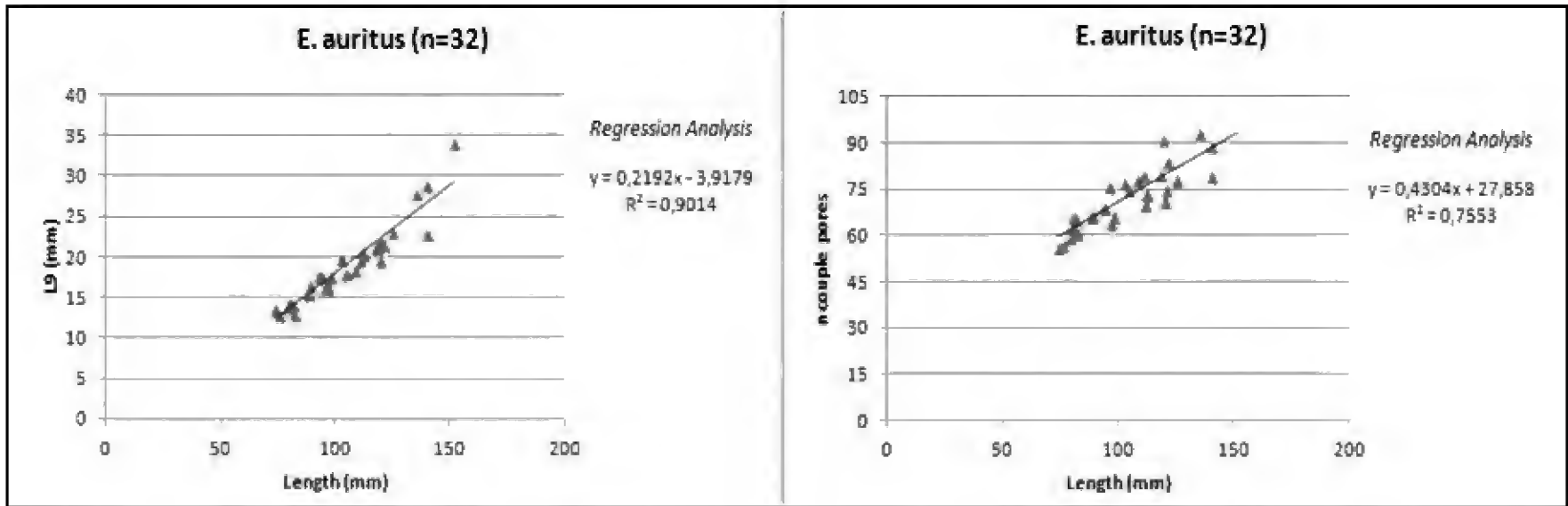Figure 4. Ratio between number of plates and echinoids size, in a sample from Mangili, Tulear, Madagascar.

Figure 5. Ratio, by increasing dimension, between odd petals and corresponding number of pores.

Specimen	Dap	L5	L7	L9	couple of pores
IVM82	74	5.3	13.06	13.55	56
IVM83	75.6	14.3	12.65	12.8	57
IVM84	78.7	15.7	14.45	13.85	59
IVM85	79.3	17.1	14.3	14.3	63
IVM86	80.2	17.8	15.2	14.3	66
IVM87	81.3	18	14.5	14.3	65
IVM88	82.2	16	13.5	13	61
IVM89	88	18.2	15.6	15.4	66
IVM90	88.3	18.4	15.5	15.4	67
IVM91	88.6	18.8	16.8	16.5	66
IVM92	92.9	20.3	18.2	17.8	69
IVM93	93.7	20.8	17.8	17.45	69
IVM94	95.6	20.6	17.3	16.2	76
IVM95	96.5	19.7	17.85	16.35	64
IVM96	97.9	19.5	16.65	17.45	66
IVM97	102.5	21.8	18.5	19.7	77
IVM98	104.2	22.4	17.95	17.95	75
IVM99	108.2	21.8	18.65	18.25	78
IVM100	110.8	23.4	20.3	19.55	80
IVM101	111.4	23.4	21	20.55	70
IVM102	111.8	23.8	19.6	20.5	74
IVM103	112	24.8	20.6	20.3	73
IVM104	117.8	25.4	21.7	21.25	80
IVM105	119.2	26.4	23.3	21.75	91
IVM106	119.7	23.1	19	19.65	71
IVM107	120.7	24	21.05	21.35	75
IVM108	120.8	25.2	20.9	21.6	84
IVM109	124.9	25	23.35	23	78
IVM110	134.9	32.1	28.8	27.8	93

Table 4 (upper). Data of petals dimension and corresponding number of pores in ambulacral areas of "*Echinodiscus*"cf. *auritus*, Recent, from Mangili.

Table 5 (right). Data of interambulacra disjunction variability in "*Echinodiscus*" cf. *auritus*, from Mangili: C = Continuos; D = disjoint; A = Amphiplacous; M = Meridoplacous.

Specimen	Ia1	Ia2	Ia3	Ia4	Ia5	plates	pos Pt
IVM82	D-M	D-A	D-A	D-M	D-A	4a-5b	2a-2b
IVM83	C-M	C-A	C-A	C-A	D-A	4a-4b	2a-2b
IVM84	D-M	D-A	C-A	C-M	D-A	4a-4b	2a-2b
IVM85	D-M	C-A	C-A	D-M	D-A	4a-5b	2a-2b-3b
IVM86	C-M	C-M	C-A	C-A	D-A	4a-5b	2a-2b
IVM87	C-A	C-A	C-A	C-M	D-A	4a-5b	2a-2b
IVM88	D-M	C-A	C-A	D-M	D-A	4a-4b	2a-2b
IVM89	D-A	D-A	D-A	D-M	D-A	4a-5b	2a-2b
IVM90	D-M	D-A	C-A	D-M	D-A	4a-4b	2a-2b
IVM91	D-M	C-A	C-A	D-A	D-M	4a-4b	2a-2b-3b
IVM92	D-M	D-A	D-M	D-M	D-A	4a-5b	2a-2b
IVM93	D-M	C-A	D-A	D-M	D-A	4a-4b	2a-2b
IVM94	D-M	D-A	D-A	D-M	D-A	4a-4b	2a-2b
IVM95	C-A	C-A	C-A	D-M	D-A	4a-4b	2a-2b
IVM96	D-M	D-M	C-A	D-M	D-A	4a-5b	2a-2b
IVM97	D-A	D-A	C-M	D-A	D-A	5a-5b	2a-2b
IVM98	C-M	C-A	C-A	C-M	D-A	4b-5a	2a-2b
IVM99	D-M	D-A	D-A	C-M	D-A	4a-5b	2a-2b
IVM100	C-M	D-A	C-A	C-A	D-A	5a-5b	2a-2b
IVM101	D-M	D-A	C-A	D-M	D-A	4a-5b	2a-2b
IVM102	C-A	C-A	C-A	C-M	D-A	4a-4b	2a-2b
IVM103	C-A	C-A	C-A	C-M	D-A	4a-5b	2a-2b
IVM104	-	-	-	-	-	4a-4b	2a-2b
IVM105	C-M	D-A	D-M	D-M	D-A	4a-5b	2a-2b
IVM106	C-M	C-A	D-A	C-A	D-A	4a-5b	2a-2b
IVM107	C-M	D-A	C-A	D-A	D-A	4a-5b	2a-2b
IVM108	C-M	C-A	C-A	C-M	D-A	4a-5b	2a-2b
IVM109	C-A	D-A	D-A	D-A	D-A	4a-4b	2a-2b
IVM110	D-A	D-A	D-A	D-A	D-A	4a-4b	2a-2b
IVM111	C-A	C-A	D-A	D-A	D-A	4a-5b	2a-2b
IVM112	D-M	D-A	D-A	D-M	D-A	4a-4b	2a-2b
IVM113	D-M	D-A	D-A	D-M	D-A	4a-4b	2a-2b
IVM081	D-A	D-M	D-A	D-M	D-A	4A-4b	2a-2b
IVM206	D-M	D-A	D-A	D-M	D-M	5A-5B	2a-2b
IVM207	D-M	D-A	D-A	D-M	D-A	4A-4B	2a-2b
IVM208	D-M	D-A	D-A	D-M	D-M	4A-5B	-
IVM210	D-M	D-A	D-A	D-M	D-M	4a-5b	2a-2b
IVM209	D-M	D-A	D-A	D-M	D-M	4a-4b	2a-2b
IVM211	D-M	D-A	D-A	D-M	D-M	4a-4b	2a-2b
IVM212	D-M	D-A	D-A	D-M	D-M	4a-5b	2a-2b
IVM213	D-M	D-A	D-A	D-M	D-M	4a-4b	2a-2b
IVM214	D-M	D-A	D-A	D-M	D-M	4a-4b	2a-2b
IVM215	D-M	D-A	D-A	D-M	D-M	4a-4b	2a-2b

Specimen	Apical disc	PL	WA	ß
IVM82	4.5	39	34	55
IVM83	5	38	31	53
IVM84	4.5	38	32	57
IVM85	4.5	40	29	49
IVM86	4.5	40	33	58
IVM87	4.5	38	30	56
IVM88	4.5	36	32	56
IVM89	4.5	39	32	50
IVM90	4.5	38	32	54
IVM91	6	40	34	59
IVM92	5.5	41	32	54
IVM93	5.5	41	32	56
IVM94	5.5	38	31	57
IVM95	5	39	33	62
IVM96	5	39	33	54
IVM97	5.5	43	33	57
IVM98	5.5	41	32	53
IVM99	5.5	38	29	58
IVM100	4	39	35	56
IVM101	5	41	31	53
IVM102	5.5	41	32	53
IVM103	5	43	31	56
IVM104	5	41	33	55
IVM105	6	42	33	57
IVM106	5.5	38	31	59
IVM107	5	37	31	48
IVM108	4.5	40	37	
IVM109	5	40	31	54
IVM110	4.5	43	32	53
IVM111	4.5	38	34	65
IVM112	6	47	37	55
mean	5.6	39.8	32.3	55.4
Range	4 - 6	36 - 47	29 - 37	48 - 62

Table 6. Data of apical disc, PL, WA at ambitus on interamb. 5, and angle ß, in "*Echinodiscus*" cf. *auritus*, from Mangili.

The same can be said about the variation of PL, which is higher (37–48% TL) in the sample of Mangili compared to that of the Philippines (40–48% TL) but with an average much lower (41 versus 43% TL). Also the variation of L11 is high enough, but similar in the two samples (21% TL). Even the measurement of WA to the interambulacrum 5 and of the ß angle, shows normal variability, but, already at a first comparison with data from other species of "*Echinodiscus*", it seems to provide significant results.

In fact, the low average of WA and the low grade of ß, together with the still stretched shape, makes these echinoids very characteristic and separates them significantly from other groups of the same family.

This will be useful to make direct comparisons between samples of "*Echinodiscus*" and *Amphiope*, as done by Stara & Sanciu (2014).

CONCLUSIONS

Tests and observations obtained allow us to several considerations. The variability of the notches, and in particular of the L1 is quite high, while that of L2 is not verifiable because of frequent malformations, however, these variability does not seem to change the appearance of these echinoids. The same consideration should be made for the variability of the periproct position in respect to the posterior margin. This is always very high when compared with that detected in other specimens of *Echinodiscus* seen in the literature (see Stara & Sanciu, this volume). Other measurements taken do not appear to show significant levels of variability. In reference to the plating (pattern plate), there is a great variability in the disjunction of the post basicoronals in interambulacra 1, 2, 3 and 4. An analysis of this unexpected appearance is shown in Stara & Sanciu (2014). Very important results relate to other fundamental aspects for all those who will compete in this family's systematic. Specifically, it was possible to detect a marked stability in the development of the scheme of interambulacrum 5 and in that of the adjacent ambulacra I and V.

In fact, the periproct position and the plate shape in interambulacrum 5, are very stable in both studied samples. Also the plates number per column

	5a or	5a ab	Σ	5 or	5b ab	Σ	Ia or	Ia ab	Σ	Ib or	Ib ab	Σ	1a or	1a ab	Σ	1b or	1b ab	Σ	IIa or	IIa ab	Σ	IIb or	IIb ab	Σ	IIIa or	IIIa ab	Σ	IIIb or	IIIb ab	Σ
IVM82	4	9	13	4	10	14	6	8	14	6	8	14	3	9	12	4	9	13	4	7	13	5	7	12	5	6	11	5	7	12
IVM83	4	9	13	3	10	13	6	6	12	6	7	13	4	9	13	3	9	12	6	6	12	5	6	11	6	7	13	7	6	13
IVM84	3	9	12	3	10	13	6	7	13	6	7	13	3	9	12	4	9	13	5	5	10	6	6	12	6	6	12	5	7	12
IVM85	3	10	13	4	10	14	6	7	13	5	7	12	3	10	13	4	10	14	6	6	12	6	7	13	6	7	13	6	6	12
IVM86	4	9	13	4	9	13	7	6	13	6	5	11	4	10	14	3	10	13	7	6	13	6	7	13	7	6	13	6	7	13
IVM87	4	10	14	4	10	14	7	8		6	7	13	4	10	14	4	10	14	6	6	12	6	7	13	6	7	13	6	6	12
IVM88	3	10	13	4	9	13	5	8	13	6	7	13	4	9	13	3	10	13	6	7	13	6	7	13	5	7	12	5	8	13
IVM89	4	9	13	4	9	13	6	7	13	7	7	14	3	9	12	4	10	14	6	7	13	6	7	13	6	6	12	6	7	13
IVM90	3	10	13	4	10	14	6	7	13	7	8	15	3	10	13	4	9	13	5	6	11	6	7	13	6	6	12	5	7	12
IVM91	4	10	14	4	10	14	6	8	14	6	8	14	3	9	13	4	10	14	6	6	12	6	7	13	6	7	13	6	7	13
IVM92	3	9	12	4	10	14	6	7	13	6	7	13	3	9	12	4	10	14	5	6	11	5	6	11	5	6	11	5	6	11
IVM93	3	9	12	4	9	13	6	7	13	6	7	13	3	10	13	4	10	14	5	6	11	5	6	11	5	6	11	5	6	11
IVM94	4	10	14	3	10	13	6	6	12	6	7	13	3	10	13	4	10	14	7	7	14	5	6	11	6	7	13	6	7	13
IVM95	3	10	13	3	9	12	5	7	12	6	7	13	3	10	13	4	10	14	5	7	12	5	7	12	5	7	12	5	7	12
IVM96	4	8	12	4	9	13	6	7	13	6	8	14	3	10	13	4	10	14	5	7	12	6	7	13	5	6	11	6	6	12
IVM97	4	10	14	4	10	13	6	7	13	6	8	14	3	11	14	4	10	14	5	7	12	6	7	13	6	6	12	5	7	12
IVM98	4	11	15	3	10	13	6	7	13	7	8	15	3	10	13	4	10	14	6	7	13	5	6	11	6	7	13	5	7	12
IVM99	3	10	13	4	11	15	6	7	13	7	7	14	4	10	14	4	10	14	5	6	11	6	6	12	5	6	11	4	7	11
IVM100	4	10	14	4	11	15	6	8	14	7	8	15	3	10	13	4	10	14	6	6	12	6	7	13	5	7	12	5	8	13
IVM101	4	10	14	4	10	14	6	7	13	7	7	14	4	9	13	5	9	14	6	7	13	6	6	12	7	6	13	6	7	13
IVM102	3	11	14	4	10	14	6	7	13	7	8	15	3	10	13	4	10	14	6	7	13	5	7	12	5	7	12	5	6	11
IVM103	3	8+		4	8+		6	8	14	7	8	15	3	11	14	4	10	14	5	7	13	6	7	13	5	6	11	5	7	12
IVM104																														
IVM105	3	10	13	4	10	14	6	8	14	6	8	14	3	10	13	4	10	14	5	7	12	5	8	13	5	7	12	4	7	11
IVM106	3	9	12	4	10	14	6	8	14	6	8	14	3	11	14	4	10	14	6	8	14	5	7	12	6	6	12	6	7	13
IVM107																														
IVM108	4	10	14	4	10	14	6	7	13	8	7	15	3	10	13	4	10	14	5	6	11	6	6	12	6	7	13	5	7	12
IVM109	3	10	13	4	10	14	5	7	12	7	8	15	4	10	14	4	11	15	5	7	12	5	8	14	5	7	12	5	7	12
IVM110	3	10	13	3	—		6	7	13	6	7	13	3	10	13	4	10	14	6	7	13	5	6	13	5	7	112	5	7	12
IVM111																														
IVM112	3	10	13	3	10	13	6	9	15	6	9	15	3	11	14	4	11	15	5	7	12	5	7	12	5	7	12	5	7	12
IVM113	3	11	14	4	10	13	6	8	14	6	7	13	3	10	13	4	11	15	5	7	12	5	8	14	5	7	12	5	7	12

Table 7. Numbers of plates (post basicoronal only) in some ambulacra and interambulacra in the sample of "*Echinodiscus*" cf. *auritus* from Mangili. or = oral side; ab = aboral side; Σ = summa of oral + aboral number of plates.

	TL - 5 oral	TL - 5 aboral	TL - 3 aboral
(a) r_s	0.267	0.173	-0.218
(b) r_s (0.05; 27)*	0.382	0.382	0.382
If a < b then H_0: ρ_s = 0	TRUE	TRUE	TRUE

Table 8. * Critical value of the Spearman rank correlation rs (α, n), with α = 0.05 and n = number of samples. This value is extract from the table of critical values obtained through the software SuppDist (Wheeler, 2005) implemented in R and based on the method of Kendall & Smith (1939).

relative to interambulacrum 5 and to the two adjacent ambulacra seem to be very stable for all size classes considered (see diagram in Fig. 4). On the contrary, it was observed a good linear relationship between the petals length and sample size. It is considered, for each sample, the petaloid III with the relative increase of the number of pairs of pores (Fig. 5).

Is interesting to note that, despite the significant variability of L11, the position of the periproct, compared to the scheme of the plates of these echinoids does not vary.

Also the size of PL, WA and ß seems to characterize these echinoids, particularly since, already at a first glance, it distinguishes them very well, from other groups of the same family, as you can see better in Stara & Sanciu (2014). Even the observation of the structure of the floor of the central hollow, which seems to differ from that of other genera like, for example, *Amphiope*, it may be helpful for future comparisons between species of genera apparently neighbours, through the work of those correlations.

Is very important, finally, the difference in Aristotle's lantern size for the same TL between Madagascar and Philippines specimens (Plate 6).

This suggests that there may be two distinct species, but this will be subject of another work.

ACKNOWLEDGEMENTS

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Analysis of some astriclypeids (Echinoidea Clypeasteroida)

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ABSTRACT

The systematic position of some astriclypeid species assigned through times to the genera *Amphiope* L. Agassiz, 1840 and *Echinodiscus* Leske, 1778 is reviewed based on the plating pattern characteristics of these two genera universally accepted, and on the results of new studies. A partial re-arrangement of the family Astriclypeidae Stefanini, 1912 is herein proposed, with the institution of *Sculpsitechinus* n. g. and *Paraamphiope* n. g., both of them characterized by a peculiar plating-structure of the interambulacrum 5 and of the ambulacra I and V. Some species previously attributed to *Amphiope* and *Echinodiscus* are transferred into these two new genera. Two new species of Astriclypeidae are established: *Echinodiscus andamanensis* n. sp. and *Paraamphiope raimondii* n. sp. Neotypes are proposed for *Echinodiscus tenuissimus* L. Agassiz, 1840 and *E. auritus* Leske, 1778, since these species were still poorly defined, due to the loss of the holotypes and, for *E. auritus*, also to the unclear geographical/stratigraphical information about the type-locality. A number of additional nominal fossil and extant species of "*Echinodiscus*" needs revision based on the same method.

KEY WORDS   Astriclypeidae; *Amphiope*; *Paraamphiope*; *Echinodiscus*; *Sculpsitechinus*; Oligo-Miocene.

Received 28.02.2014; accepted 14.03.2014; printed 30.06.2014
Paolo Stara (ed.). Studies on some astriclypeids (Echinoidea Clypeasteroida), pp. 225–358.

INTRODUCTION

The classification of the astriclypeid echinoids *Amphiope* L. Agassiz, 1840 and *Echinodiscus* Leske, 1778 have been traditionally based on the external morphological features, mainly test outline, size and shape of lunules and petals (see Durham, 1955). Structural characters, largely used in the taxonomy of other clypeastroids, were practically ignored in earlier studies dealing with these genera, and although several species have been described in the literature, important features for species-level taxonomy, such as oral plating, were poorly illustrated or omitted completely.

MATERIAL AND METHODS

The studied specimens are housed in the following public institutions: MAC (Museo di Storia Naturale Aquilegia) and UNICA (Department of Animal Biology and Ecology, University of Cagliari) Cagliari, Italy; MSNDG (Museo di Storia Naturale Doria, Genoa) and UNIGE.SM (Dip.Te. Ris, University of Genoa), Genoa, Italy; NHMUK (National History Museum of United Kingdom) London, England; ZM (Zoological Museum of Denmark, University of Copenhagen) Copenhagen, Denmark; PMBC (Phuket Marine Biological Centre), Phuket District, Thailand.
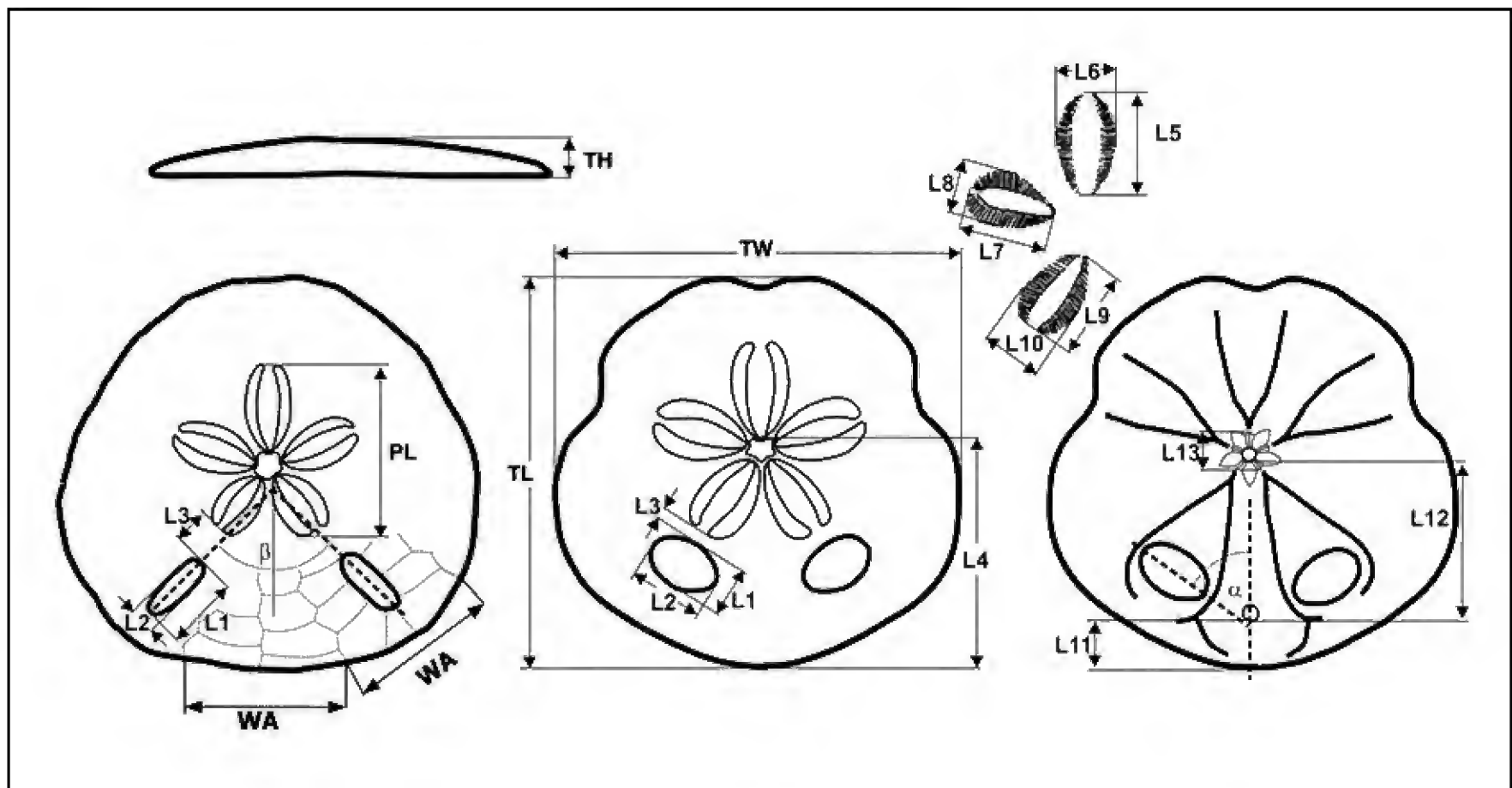
Figure 1. Biometric parameters measured in the studied samples.

Some other specimens, used for comparison, are kept in private collections, as cited.

43 specimens attributed to *Echinodiscus* and 29 to *Amphiope* were examined. 8 *Amphiope* fossils from Touraine, France; 1 *Echinodiscus* fossil from Hurgada, Egypt; 1 "*Amphiope*" fossil from Liguria, Italy and, 1 "*Echinodiscus*" Recent from Lembeh, North Sulawesi, Indonesia; 2 *Echinodiscus* Recent from Nosy Be, Madagascar; 33 "*Echinodiscus auritus*" Recent from Mangili, Madagascar; 10 "*Echinodiscus*" Recent from Philippines; 1 "*Echinodiscus*" Recent from Indonesia (Borneo) are housed in MAC; after study, some specimens will be deposited at the UNICA; 3 "*Amphiope*" fossils from Liguria, housed to the MSNDG and 2 fossil specimens of "*Amphiope*" at the UNIGE.SM (Dip. Te. Ris); 21 *Echinodicus* and 10 "*Amphiope*" at the NHMUK; 1 "*Echinodiscus*" at the ZM; 6 *Echinodiscus* at the PMBC.

Three specimens of "*Echinodiscus*" used for comparison belong to private collections; some plating patterns were taken from illustrations reported in the literature.

Measures taken as in figure 1. The plating pattern follows Durham (1955) and, when possible, includes both sides of the specimen. To highlight the sutures, humidification by denatured ethyl alco-hol has been used for extant species, a mixture of water and hydrochloric acid (ca. 2%) for some fossil specimens. The internal structure was studied by sectioning the test, and in some cases by X-ray. Morphological abbreviations as in figure 2: ß = angle between major axis of the two lunules; TL = test length; TW= test width; TH = test height; L1-L2 = lunule length and width, respectively; L3 = distance between posterior petal-tip and lunule, L4 = distance between apical system-posterior margin, L5-L6 = length and width of the frontal petal, respectively; L7-L8 = length and width of the anterior paired petal, respectively; L9-L10 = length and width of the posterior petal, respectively; L11 = distance between periproct-posterior margin test; L12 = distance between the posterior border of the peristome and of the periproct, L13 = front-rear diameter of the ambulacral basicoronal circlet. PL = petalodium lenght; WA= ambulacral and interambulacral width at ambitus; ø pc = periproct diameter; ø ps = peristome diameter ; Σ = summation. To describe the lunules shape and dimension into a numeric value, we introduced a Shape Index (SI) corresponding to the ratio L2/L1 and a Width Index (WI) = (L1 + L2) / 2.

Species with doubtful taxonomic attribution are marked by quotation marks.

I. DESCRIPTION OF THE SAMPLES EXAMINED

"*Amphiope*" sp.
Plates 1, 2; Tables 1, 2

EXAMINED MATERIAL. Eight specimens from Channay-sur-Lathan, Touraine, France, Late Serravallian-Early Tortonian, TL 47 - 73 mm.

DESCRIPTION. Small to medium sized echinoid with low test and small rounded lunules. The lunules show a low variability range: SI ranges from 1 to 1.6 (lunules roundish to slightly transversely elongated), WI ranges from 9 to 10.5 (small lunules). In this sample, the lunules variability equals on the average 34% L1 and 27% L2.

In the oral interambulacrum 5 there are only the post-basicoronal plates 2a, 3a and 2b, 3b and, in some cases, a small portion of 4b. The plate 2a is long and staggered with respect to 2b; the periproct opens between 2a/3b. Aborally, the tips of the posterior petals are separated from the lunules by 1 or 2 couples of plate.

"*Amphiope*" *pedemontana* Airaghi, 1901

EXAMINED MATERIAL. Rupelian, Piedmont and Liguria, Italy. The holotype was housed in the Civic Museum of Natural History of Milan; it was lost during the Second World War. The specimens in the Genoa museum indicate the occurrence of two different morphotypes under this name: one of them corresponds to the description of "*Amphiope*" *pedemontana* Airaghi, 1901, the other seems different.

First morphotype
Figures 2a, b; Table 3

EXAMINED MATERIAL. Three specimens: MSNDG. N25 from Pareto, MSNDG. N1214 from Cairo Montenotte and MSNDG.N1218 from unknown locality, TL 53 ÷ 61 mm; two illustrations given by Airaghi (1899 and 1901) of a specimen from Dego and another one from Santa Giustina; one specimen from Merana: MAC.PL2014, TL, 71 mm, TH 7 mm.

DESCRIPTION. Small to medium sized form, with small axial lunules, small and open petals, very depressed test and drop-shaped periproct. In the oral interambulacrum 5 there are only the post-basicoronal plates 2a, 3a and 2b, 3b, all of them large and paired; the periproct opens between plates 2a/3b (Figs. 2a, b).

Second morphotype
Fig. 2c; Table 3

EXAMINED MATERIAL. Two whole specimens (UNIGE.SM-VI-P-(5)-DN and UNIGE.SM-VI-DR) and 2 test fragments, from Pareto.

Specimen	TL	TW	TH	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	oPc	oSto
PL1668	68	101	12	8.5	9	9	58	25	13	24	15	23	15	5.5	43	13	2	3
PL1669	70	101	12	7.5	12	7.5	56	26	15	25	15	24	14	5.5	43	14	2	4
PL1921	47	104	15	8.5	10	9.5	55	25	13	24	13	22	13	3.5	46	14	1	5
PL1822	50	100	15	10.5	10	7.5	56	26	14	23	14	24	14	5	43	12	1.5	5
PL1823	49	106	14	9	10	9.5	56	24	14	23	14	22	14	4.5	44	12	1.8	4.5
PL1824	55	102	16	9	12	7	57	26	15	23	15	22	15	3.5	46	13	1.8	4.5
PL1825	61	101	16	8	10	8.5	56	26	14	24	15	23	15	5	44	12	1.8	5
PL1826	73	101	16	9	12	6.5	57	26	15	25	15	24	15	7	43	13	1.5	2.5
mean		102	14	8.7	11	8.1	56	25	14	24	14	23	14	4.9	44	13	1.6	4.2

Table 1. Morphometric data of *Amphiope* sp. 3. TL in mm, other measures in % TL.
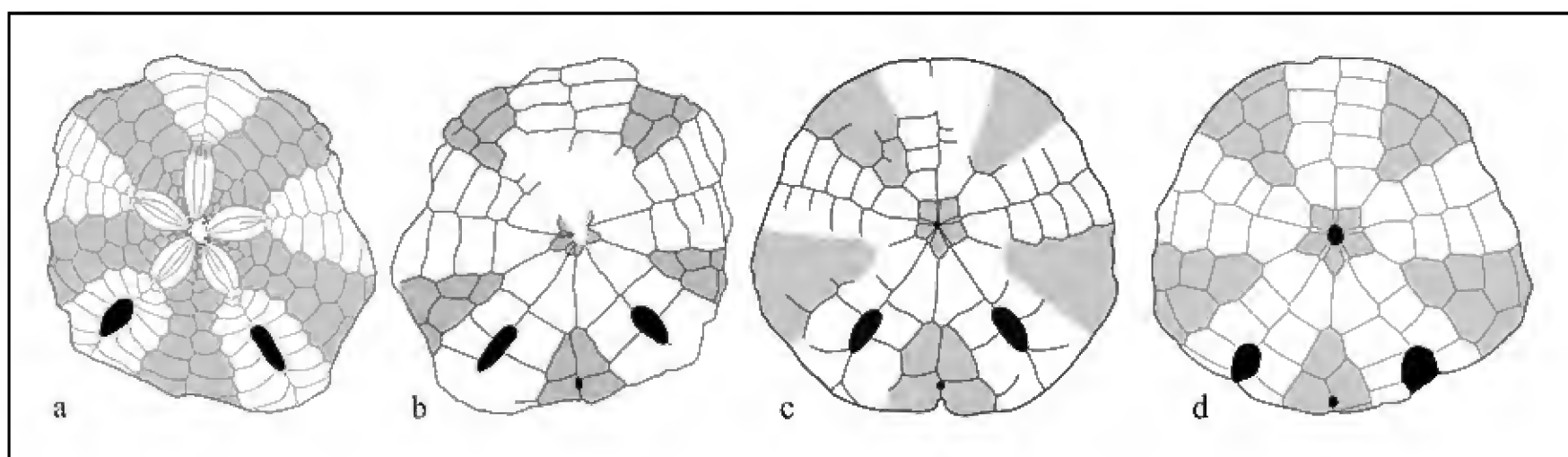
Figure 2. "*Amphiope*" *pedemontana* (Oligocene, Liguria and Piedmont, Italy): a, b: respectively, aboral and oral plate structure of MSNDG.1218; c: "*Amphiope*" sp. 1 (Oligocene, Liguria and Piedmont, Italy), oral plate structure of UNIGE.SM-VI-P5-DN; d: "*Amphiope*" *arcuata* (Miocene, Libya), oral plate structure.

Amphiope sp. 3	TL	Apx	PL	WA	α
PL1668	68	8	51	36	52°
PL1669	70	8	53	33	64°
PL1821	47	8	52	29	54°
PL1822	50	8	52	32	71°
PL1823	49	8	50	32	-
PL1824	55	8	53	-	67°
PL1825	61	8	53	-	64°
PL1826	73	8	53	30	53°
mean		8	52	32	60.7°
range			50-53	29-36	52-71

Table 2. Apx, PL, WA and ∝ *data of Amphiope* sp. 3.
TL in mm, ∝ in degree, other measures in % TL.

DESCRIPTION. Small sized form with closed petals and a notch along the posterior margin, close to the periproct. The periproct is rounded and opens between plates 2a/3b. In the interambulacrum 5 there are only the post-basicoronal plates 2a, 3a and 2b, 3b, that are large and paired.

"*Amphiope*" *arcuata* Fuchs, 1882
Fig. 2d; Table 4

EXAMINED MATERIAL. Five specimens from the "Miocene" of the Libyan desert (locality not specified), housed in the NHMUK (code E1671-2, E1674-6), TL 35-79 mm.

DESCRIPTION. Small to medium sized echinoid, with very low test and thin ambitus; test outline rounded or sub-trapezoidal. In the interambulacrum 5 there are two plates per column: 2a, 3a and 2b 3b; the plates 2a/2b are staggered. These specimens are characterized by small ovoid axial lunules, distant from the corresponding petal tips. Lunules show a low variability since SI ranges from 0.45 to 0.76 (axially elongated lunules) and WI ranges from 8 to 10.5 (small lunules). On average the lunules variability equals 34% of L1 and 27% of L2. PL ranges from 42 to 46% TL.

"*Amphiope*" *duffi* Gregory, 1911
Plate 3 Figs. 1–6

EXAMINED MATERIAL. Rupelian, Libya. Two syntypes housed in the NHMUK: CY66/E11350, from Sidi Rof Diasiasia, Cyrenaica, TL = 37 mm and Cy264/E11349, from Aïn Sciahat, Cyrenaica, TL = 39 mm.

DESCRIPTION. Small and low test with thin ambitus; test outline sub-rounded. Adoral face unknown. Width of the interambulacrum 5 at the ambitus about 23% TL. In Cy66 the petals are distally open. Petals are sub-equally sized; PL = 47%

TL. Lunules are apparently open (notches?), but it is not clear whether this is due to damage; in C66 they are very small and ellipsoidal. ß measures 65°. On the aboral side each lunule is separated from the petal tip by 3-4 couples of plates and is surrounded by 3 - 4 couples of plates. The apical disc is small (≈ 8% of TL) and star-shaped. The internal structure is unknown. Number of plates per column only partially visible (see Table 7).

"*Echinodiscus tenuissimus*" L. Agassiz, 1847

EXAMINED MATERIAL. Recent, Indian Ocean, In-donesian Archipelago, Oceania and China Sea.

REMARKS. The holotype was established by L. Agassiz (1847) in Agassiz & Desor (1847) on the basis of a specimen with small axial lunules, from Waigiu (New Britannia, Western Papua, Indonesia) and housed at the Museum of Natural History, Paris. Actually the holotype is wanting (personal commu-niation by Sylvain Charbonnier, June.03.2014). The group of Recent specimens under study indicate the occurrence of three different morphotypes: one of them shows some characteristics of the genus type *E. bisperforatus* Leske, 1778, the others seem different.
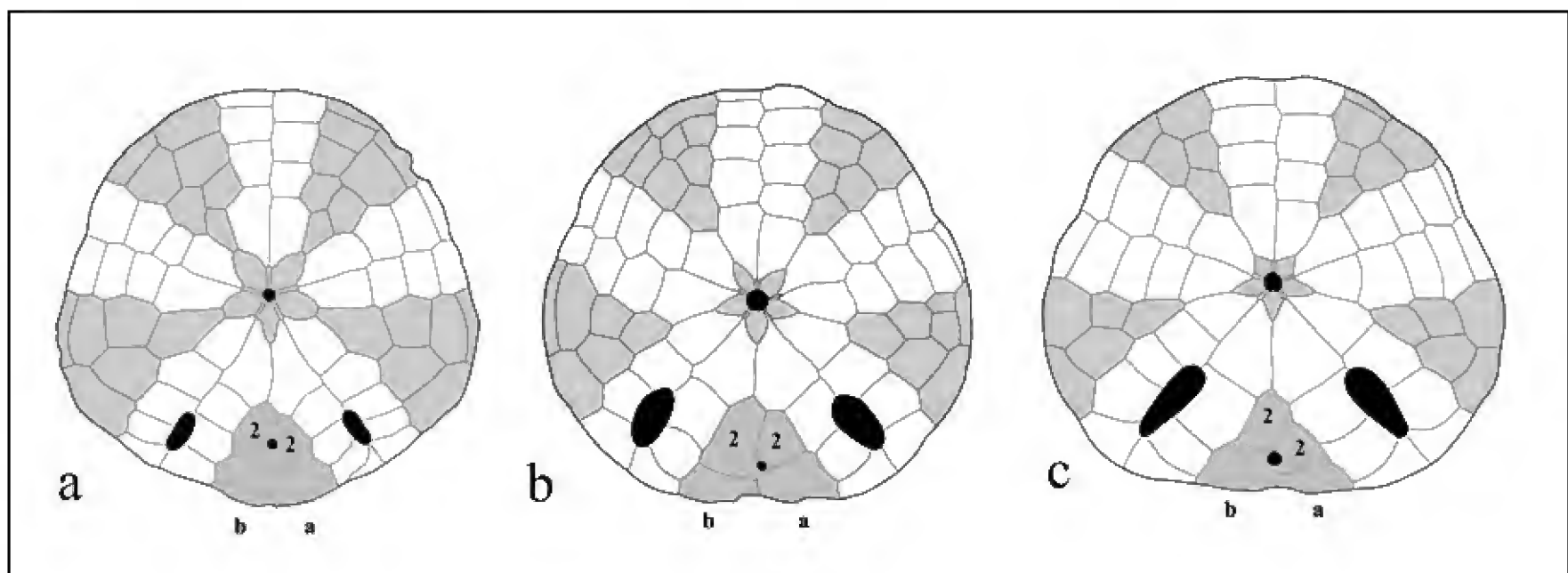
Figure 3. Plate structures of adoral side of the "*Echinodiscus tenuissimus*" morphotypes; postbasicoronal plates of interambulacrum 5 colored - a, first morphotype; b, second morphotype; c. third morphotype.
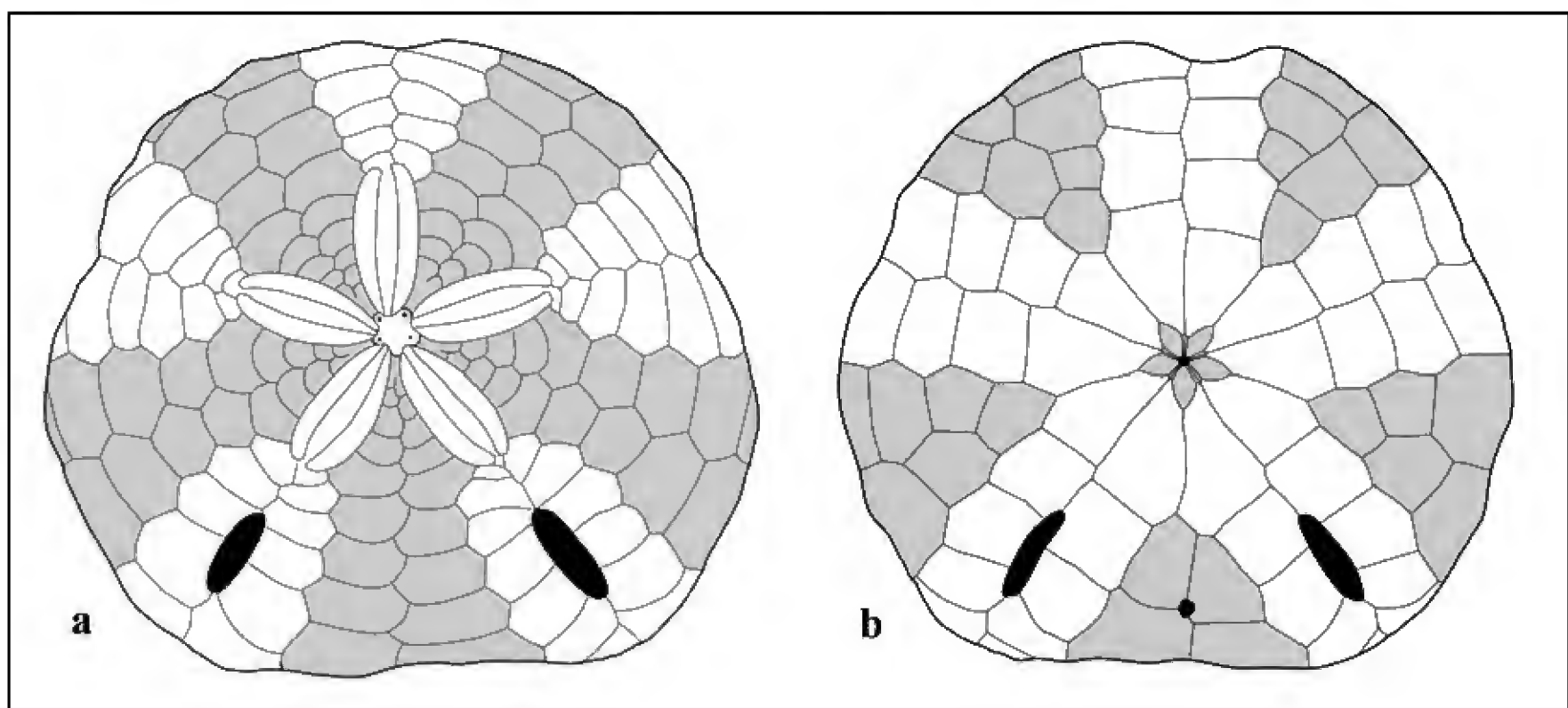
Figure 4. "*Echinodiscus bisperforatus truncatus*", plate pattern of oral (a) and aboral sides (b).

Specimen	TL	TW	TH	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	øPc
MSNDG.25	61	103	13	18	7.5	7	52	21	8.5	18	8	17	8.5	7	38	-	3.5
MSNDG.1214	55	118	14	15	7.5	8	55	-	11	20	11	20	11	7	-	-	-
MSNDG.1218	53	95	14	13	7	8	54	20	9	18	9.5	16	9.5	7	38	-	3.5
MAC.PL2014	71	112	10	10	5	8	56	21	8.5	20	9	20	8	7	43	-	2.5
Mi-Ai-1901	53	90	15	15	6	9	52	23	10	18	8.5	18	10	6	-	-	-
Mi-Ai-1899	-	85	-	18	5	6	50	22	10	17	8	20	9.5	>5	46	-	-
UNIGE.SM-IV-DN	76	104	10	15	7	8	54	23	9	20	9.5	18	8	7	43		-
UNIGE.SM-VI-DR	75	197	11	15	7	-	54	24	12	22	12	-	-	-	-	-	-
Mean		101	10	15	7	8	52	22	9.7	19	9.5	18	9.2	6.7	42		

Table 3. M morphometric data of *Echinodiscus pedemontanus* (former *Amphiope pedemontana*)
and *Echinodiscus* sp. 1. TL in mm, other measures in % TL.

1	TL	TW	TH	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	øPc	øSto
NHMUK.E76161	79	102	6	9.5	6.5	15	55	22	11	20	11	21	12	12	39	13	1.8	3.5
NHMUK.E76162	66	103	6	12	7	15	55	20	10	19	10	20	10	13	-	-	2	4
NHMUK.E76166	49	100	12	11	5	14	55	22	10	18	11	18	10	13	33	13	1.8	4
NHMUK.E76165	40	100	11	12	9.5	15	54	22	11	18	19	18	10	5	45	15	2	4
NHMUK.E76164	35	106	11	12	8.5	15	54	22	11			21	11	4				
Mean		102	9	11	7.3	15	55	22	11	19	12	20	11	9.7	39	14	1.9	3.8

Table 4. Morphometric data of *Paraamphiope arcuata* (former *Amphiope arcuata*). TL in mm, other measures in % TL.

First morphotype
Fig. 3a

EXAMINED MATERIAL. One specimen from Lembeh Channel, North Sulawesi (Indonesia), MAC. IVM 207, TL = 50 mm; one specimen from New Caledonia, NHMUK.1981.11.2.25, TL = 112 mm; one specimen from Palau, Micronesia, NHMUK.59.7.1.14, TL = 120 mm; two specimens from Lembeh Channel, North Sulawesi (Indonesia) TL 50-65 mm from the M. Fantin collection and one from Noumea, Baie des Citrons, New Caledonia, TL 68 mm, from the F. Hattemberger collection.

DESCRIPTION. Middle size test echinoids with small slit like axial lunules and small petals. Very flat test and thin ambitus, with an elongated and more rounded anteriorly outline. In the oral interambulacrum 5 there are two-three plates in column a(2a, 3a, 4a) and three in column b (2b, 3b, 4b); in which the plates 2a and 2b are more or less staggered and the periproct opens between plates 2a/2b. The ß angle is low (65-70°, mean 67°) and WA at interambulacrum 5 is small (mean 32% TL).

Second morphotype
Fig. 3b

EXAMINED MATERIAL. Two specimens from Pak Meng Beach, Trang Province, Thailand; PMBC. 26346, 2842, TL = 81 and 66 mm; two specimens from Noparat Tara Beach, Krabi Province, PMBC.2843, 2830, TL = 66,2 and 54,6 mm; one specimen from PMBC Jetty South, Phuket, PMBC2844, TL = 66,2 mm; one specimen from West side of Ko Yao Yai, Phuket, housed in the NHMD.Z n° ZMUC-ECH-1001, TL 37 mm (see also Warèn & Crossland, 1991: figs. 10a, c); one specimen from "Thailand", Recent (based on a illustration in "www. Echinoids NL" by Bas van der Steld, Netherlands).

DESCRIPTION. Small size tests echinoids, with ovoidal axial lunules, very flat test and thin ambitus, sub-rounded in shape. In the oral interambulacrum 5 there are two postbasicoronal plates per column (2a, 3a and 2b, 3b), paired and wide. The ß angle is small (75,5°). The WA at interambulacrum 5 is about 38% TL. Since only a small sample is available to study, it is not possible to verify the variability of the lunules.

Third morphotype
Fig. 3c

EXAMINED MATERIAL. One specimen from Indonesia (Borneo), Recent, MAC.IVM206, TL = 53 mm.

DESCRIPTION. Small sized echinoid, with a flat test and slit-like axially elongated lunules. Petals small, closed distally. In the oral interambulacrum 5 there are 2 postbasicoronal plates per column (2a, 3a - 2b, 3b), with the first two staggered. The 2b is in amphiplacous contact with the first postbasicoronal plates of ambulacra I and V. Between the petal tips and the notches there are 3 couples of plates, and the periproct opens between plates 2a/3b. The WA at the interambulacrum 5 is 38% TL; the ß angle is 80°.

Echinodiscus bisperforatus truncatus
(L. Agassiz, 1841)

EXAMINED MATERIAL. Some Recent specimens examined in the Fantin collection (Venice, Italy), labeled *E. truncatus* (Fig. 4a, b), recently dredged near Singapore, allowed to observe the plate structure and other characteristics. It differs from the previous "second morphotype" by some noticeable features. The echinoids collected in Singapore have the plate pattern that match with those of the second morphotype, but have the peristome smaller, more branched food grooves, the apex much further forward, lunules longer and slit-like and the ambital outline with the posterior margin truncated. To compare other characters we took some pictures of *E. truncatus* in situ, from www.wildsingapore.com (Mega Marine Survey of Singapore) and we have established new differences, as we will see in the discussion ad in the systematics chapters.

Echinodiscus bisperforatus Leske, 1778
Plates 4, 5; Table 5

EXAMINED MATERIAL. Recent, Red Sea and Indian Ocean. Seven specimens from South Africa (locality not specified) NHMUK: NHMUK 2013.7-13, TL = 26 - 62 mm, eleven specimens from Wakiro, Massawa, Eritrea, Red Sea, NHMUK. 1965.1.11-20, TL = 46 ÷ 69 mm, one specimen from Pangani, Tanga, Tanzania, NHMUK.1957.5.21.3. TL = 84 mm; two specimens from Nosy Be Island, Northern Madagascar, TL = 25 and 45 mm, the smaller one housed at the (MAC.IVM208), and the large one from a private collection.

Specimen	TL	TH	TW	L1	L2	L11	WA	PL	ß
NHMUK.1965-6-1-11	69	9.8	115	28		12.5	54	45	101
NHMUK.1965-6-1-12	67.5	9	120	28	2.5-5	8.5	48	47	109
NHMUK.1965-6-1-13	67	11	119	31.5	2.5-5	9	51	42	103
NHMUK.1965-6-1-14	65	8.5	122	34	2.5-5	9	46	41	102
NHMUK.1965-6-1-15	65	9	113	32	-	12	-	-	-
NHMUK.1965-6-1-16	64	10	115	31	-	8	-	40	-
NHMUK.1965-6-1-17	63	9	119	28	-	9.5	52	39	110
NHMUK.1965-6-1-18	60	7.5	112	30	-	8.5	51	41	107
NHMUK.1965-6-1-19	59	8	113	31	-	7	49	38	107
NHMUK.1965-6-1-20	51	6.5	113	29	-	8	-	-	104
NHMUK.1965-6-1-21	46	6.5	109	-	-	-	47	38	-
mean		8.6	115.4	30.2	-	9.2	48	41.2	105
range		6.5-11	109-120	28-34	2.5-5	7-12.5	46-54	38-47	101-109
Specimen	TL	TH	TW	L1	L2	L11	WA	PL	ß
MAC.IVM 208	30	7	113	31	6	3.5	44	38	86
Specimens	Dap	H	Dt	L1	L2	L11	WA	P	ß
NHMUK.3013.7	62	9.5	115	34	3-3-4	5.5	50	43	103
NHMUK.3013.8	56	9	115	33.5	3-4-4.5	5.5	47	50	105
NHMUK.3013.9	54	7	116	36	3-3-3.5	5	45	45	106
NHMUK.3013.10	53.5	8	114	33.5	3-4-5	4	-	43	106
NHMUK.3013.11	47	7	115	33	3-4-5	5	47	46	108
NHMUK.3013.12	39	8	122	38	4-4-4	4	53	-	117
NHMUK.3013.13	26	7	113	31	6-6-6	3	53	-	102
mean		7.9	115.7	34	--	4.5	49	45	107
range		7-9.5	113-122	31-38	--	3-5.5	45-53		102-117
Specimen	TL	TH	TW	L1	L2	L11	R	PL	ß
NHMUK.1957.5.21-3	84	11	111	24	3.5-3.5-3	10	49	43	111

Table 5. Simplified morphometric data of *Echinodiscus bisperforatus* from different localities;
TL in mm, ß in degree, other measures in % TL.
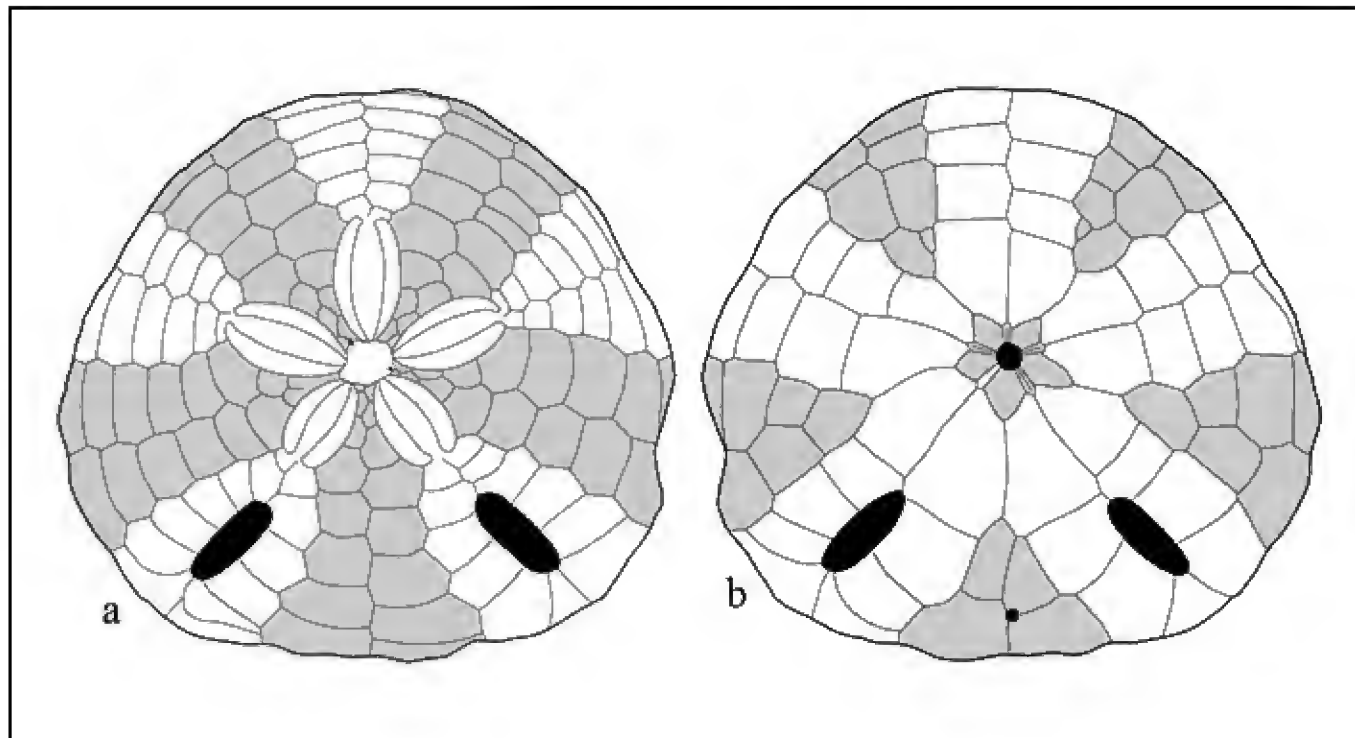
Figure 5. "*Echinodiscus* sp. 2" (Pleistocene-Holocene, Hurgada, Red Sea, Egypt), plate pattern of oral (a) and aboral sides (b).
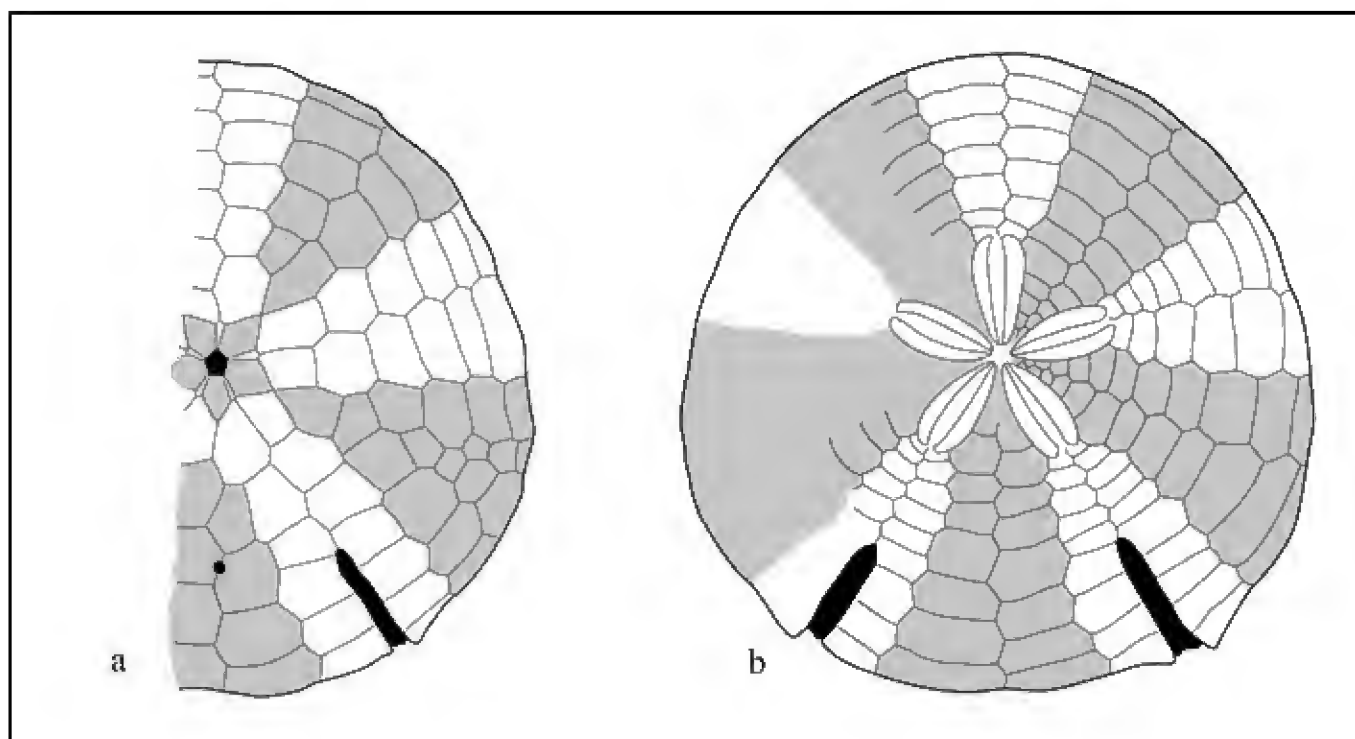
Figure 6. "*Lobophora aurita*", plate pattern, taken from the illustration by L. Agassiz (1838–41: table 14, figs. 1, 2): adoral (a) and aboral view (b).

DESCRIPTION. Middle size tests echinoids, with flat test with rounded to sub-trapezoidal outline. In the interambulacrum 5 there are two plates per column, 2a, 3a and 2b, 3b, paired and wide (see Plate 5 Fig. 2). The ß angle is about 110°; the lunules are very long and show a low variability. The WA is high (47–50% TL).

***Echinodiscus* sp.**
Fig. 5a, b

EXAMINED MATERIAL. One specimen from the Pleistocene of Hurghada, Red Sea, Egypt, MAC.PL 1850, TL = 21 mm.

DESCRIPTION. Small sized echinoid, with flat test, thin ambitus and test outline rounded. In the oral in-terambulacrum 5 there are two plates per column (2a, 3a, 2b, 3b), paired and wide. and the periproct opens between plates 2a/3b. The ß angle is 80°.

***Echinodiscus desori* Duncan et Sladen, 1883**
Plate 6 Figs. 1–6

EXAMINED MATERIAL. Four specimens from the Miocene of the Gujarat State, northern India: NHMUK.E78129, TL 49 mm; NHMUK.E724b, TL 39 mm; NHMUK.E78128a (TL 47 mm) and b (TL 47.5 mm).

DESCRIPTION. Small size and very depressed test (TH = 7 ÷ 11% TL). The ambitus is thin and with sub-rounded outline. The oral surface is exposed only in specimen NHMUK.E78128a, with the plat-

ing pattern only partially visible. The WA at the interambulacrum 5 is about 30 ÷ 35% TL in NHMUK.E724b. The petals are sub-equal in size, they are distally open or tend to opening (e.g. in NHMUK.E724b). The axial lunules are medium sized, ellipsoidal shaped. In NHMUK.E78129 they are both incomplete. The ß angle is low (68° to 74°).

"*Amphiope bioculata*" des Moulins, 1835
Plate 7 Figs. 1–11

EXAMINED MATERIAL. Based on eleven specimens illustrated by Cottreau (1914), from the Helvetian (Burdigalian in Philippe, 1998) of Saint-Cristol, Nissan, Herault; pl. VI, figs. 1–11, TL 43 ÷ 67 mm.

DESCRIPTION. Small sized echinoids, slightly wider than long (TW = 103 ÷ 110, the mean measure is 106% TL). Test depressed, however the measure of the height is unknown. The ambitus outline is sub-rounded. Inflections occur in the ambitus in correspondence with the ambulacra II, III and IV. The adoral surface is flat or slightly concave; plating not detectable. The petals are closed and sub-equal; PL ranges between 42 to 55% TL (mean 49.5% TL). The lunules are very distorted, relatively small and rounded and close to the tips of the corresponding petal. It is clear that the size variability of the lunules is high (Table 6; Figs. 11, 12), with a variation range of L1 which exceeding 50% on the average value and that of L2 which exceeds 45% on the average value. However, the SI varies from 0.95 to 1:47

Speci-mens	L1	L2	SI	WI
Fig. 1	10	9.5	0.95	9.75
Fig. 2	8	10	1.25	9
Fig. 3	12	13	1.08	12.5
Fig. 4	12	13	1.08	12.5
Fig. 5	8.5	10.5	1.23	9.5
Fig. 6	7.5	10	1.33	8.75
Fig. 7	7.5	10	1.33	8.75
Fig. 8	8	9	1.12	8.5
Fig. 9	10	14	1.47	12
Fig. 10	9	12	1.33	10.5
Fig. 11	8	11	1.37	9.5
mean	9.13	11	1.22	10.20
range	7.5-12	9-14	0.95-1.47	9-12.5
variance	49.2	45.4		

Table 6. Variability data of the lunules in *Amphiope bioculata* in Cottreau's sample.
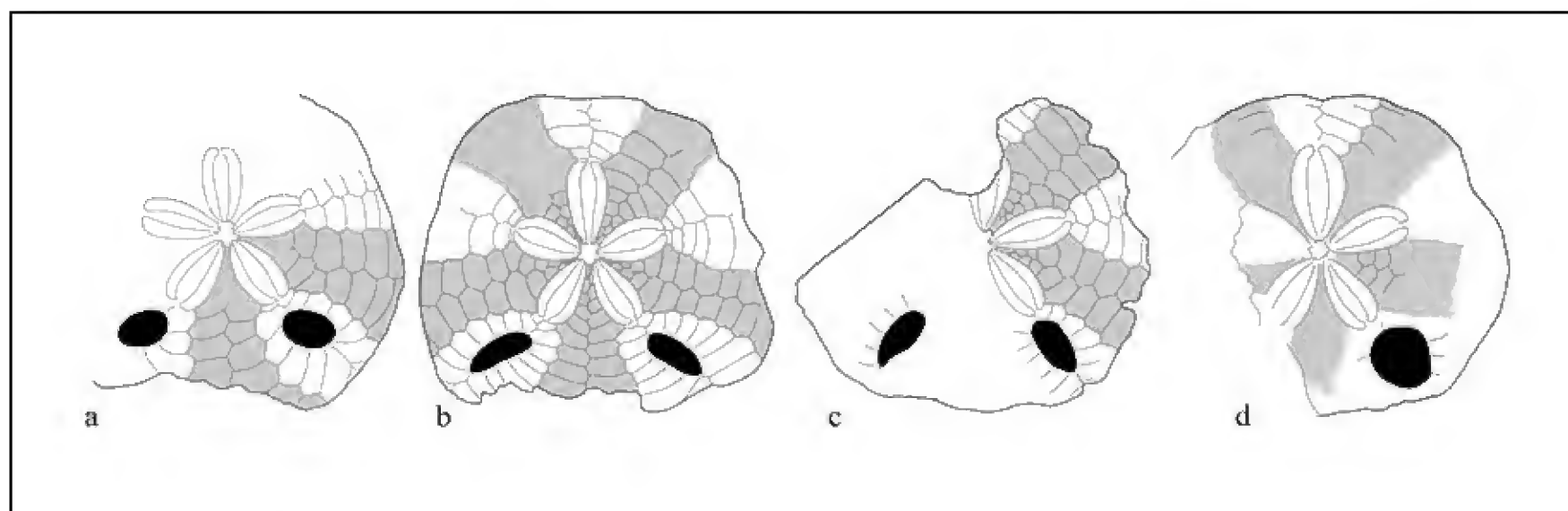
Figure 7. Aboral plate structures of "*Echinodiscus*" from Taiwan and Japan; a: *E. formosus*, ?Eocene-Miocene, Taiwan (from an illustration in Tokunaga, 1901, pl.1, figs. 1, 2); b: *E. yeliuensis*, Miocene, Taiwan (from Wang, 1984, pl. 1, fig. 2a, b); c: *E. cikuzenensis*, Oligo-Miocene, Japan (from Takano et al., 2007, pl. 1, fig. 12); d: "*E.*" *transiens*, Miocene, Japan (from Nisiyama, 1966, pl. 17, fig. 1).

while the WI ranges from 9 to 12.5, indicating that the lunules are always rounded, while varying especially in amplitude.

"*Echinodiscus auritus*" Leske, 1778
Fig. 6a, b

EXAMINED MATERIAL. Based on the illustration of *Lobophora aurita* by L. Agassiz (1841), as *L. aurita*, pl. 14, fig. 1, 2; TL 110 mm, TH 11% of TL; Recent, Red Sea, Egypt.

DESCRIPTION. Medium to large-sized echinoid with polygonal ambitus outline and two long posterior notches. The adoral surface is flat or slightly plano-concave. In the oral interambulacrum 5 there are four postbasicoronal plates per column (2a, 3a, 4a, 5a and 2b, 3b, 4b, 5b); the periproct opens far from the posterior margin (L11 = 19% TL) between plates 3b/3a. Aborally, there are 5-6 couples of plates between the notches and the posterior petal tips.

REMARKS. The illustration given by L. Agassiz (1841) was the first to highlight the plate structure of this echinoid. These data are not even reported in the recent works, for which we detect the complete plating, which is very different from those of Mangili and from the Philippines, examined by Stara & Fois M. (2014).

Echinodiscus formosus Yoshiwara, 1901
Fig. 7a

EXAMINED MATERIAL. Based on the illustration by Tokunaga (1901–3: pls. 14 and I, fig. 2); TL 100 mm. 1 specimen from Middle Eocene? to Miocene, Hatto, Kelung, Taiwan. Plating of the aboral side taken from fig. 2, pl. I; inclination of the lunules as in pl. II fig. 2.

DESCRIPTION. Medium to large sized echinoid (max TL = 140 mm), with depressed test and with sub-ellipsoidal ambitus outline. The estimated WA of the interambulacrum 5 obtained by measuring the half visible, seems to be the 50% TL. The petals are closed, sub-equal in size; Tokunaga affirms that the anterior odd petal is 25% and the other are 22.5% TL, but the illustration indicates that they all measure the 20% TL. The lunules are large and ellipsoidally shaped. The ß angle is large (111°). The lunules are surrounded by 5 pair of plates on the aboral face. The partial number of plates per column is shown in Table 7.

Echinodiscus yeliuensis Wang, 1982
Fig. 7b

Based on illustration in Wang (1984), from the Taliao Formation (Aquitanian), of Yeliu, Taiwan, pl. I, fig. 2a, b; topotype n° NTUG - [E] - 81.42; TL = 112 mm; TW = 131 mm.

DESCRIPTION. Medium to large sized echinoid with depressed test (TH = 10% TL). The ambitus outline is sub-trapezoidal, wider near the rear. Only a part of the plating of the apical surface is detectable. The estimated measure of WA at the interambulacrum 5 is 34% TL. The petals are sub-equal in size; the petalodium is wide (PL = 52% of TL). The lunules are long and narrow, broader anteriorly, lanceolate shaped and their axis deviates substantially from the corresponding petals (ß angle about 114°). There are 2 couples of plates between the petals tips and the corresponding lunules.

Echinodiscus cikuzenensis Nagao, 1928
Fig. 7c

EXAMINED MATERIAL. Based on illustration in Takano et al. (2007) pl. 1, fig. 11; 1 specimen of Education Kawai, Oligocene-Miocene in age, from Chugoku and Kyushu Province, Japan. TL unknown.

DESCRIPTION. The test outline in sub-rounded. The aboral face is incomplete. The petals are sub-equal in size; the PL is small (44% TL). The lunules are large, sub-ellipsoidal shaped and deformed and very close to the corresponding petal tip. The right lunule is surrounded by 6 couples of plates on the aboral side. The ß angle is 73°.

Echinodiscus transiens Nisiyama, 1968
Fig. 7d

EXAMINED MATERIAL. Based on the specimen illustrated in Nisiyama (1966), pl. 17, fig. 1; IGPS collection, No. 37773, from the Yamaga Formation, Miocene, Yamaguchi Prefecture, Japan. TL 102 mm.

DESCRIPTION. Medium sized, with a depressed test; TH unknown. Test outline sub-rounded. The aboral face is incomplete. The petals are sub-equal and the petalodium is wide (52% TL). The unique visible lunule is large and sub-rounded shaped.

Specimens		Ia5	Σ	amb I	Σ	amb V	Σ	Ia1	Σ	Ia4	Σ	amb II	Amb IV	Ia2	Ia3	amb III	Σ
Echinodiscus formosus	a	-		x+6				x+6				x+5		-		-	
Middle Eocene	b	x+6		x+6				x+6				x+5		-		-	
Echinodiscus pedemontanus	a	x+9		x+8		-	+	-				-		-		-	
Rupelian	b	x+8		x+8		X+7		-				-		-		-	
Echinodiscus cikizenensis	a	-		x+6				x+10				x+4		x+8		X+5	
Oligo–Miocene	b	-		x+6				x+9				x+5		x+8		-	
Echinodiscus yeliuensis	a	x+10		x+7		X+8		x+11		X+10		-		-		-	
Early Miocene	b	x+10		x+8		X+8+		x+11		X+10		-		-		-	
Amphiope nuragica	a	4+9	13	7+9	16	8+9+	17	4+11	14	4+10	14	5+4	5+4	4+6+	4+8	5+5	10
MAC.PL1684, Oligo-Miocene	b	5+10	15	8+10	18	7+9	16	3+10	13	x+11		5+4	4+4	5+6+	4+7	6+5	11
Amphiope nuragica	a	4+15	19	7+10	17	8+11	19	4+12	16	x+13		-	x+5	4+10	4+10	5+6	11
MAC.PL1680, Oligo-Miocene	b	5+14	19	7+11	18	7+10	17	x+12		4+13	17	5+5	x+6	4+11	X+10	6+5	11
Amphiope sp. 2	a	3+11	14	7+8	15	7+7	14	4+7	11	x+8		6+5+	x+4	5+10	4+11	5+5	10
MAC.PL549, Late Burdigalian	b	4+11	15	7+7	14	6+7	13	x+8+		4+7	11	6+5+	x+5	4+11	5+10	5+6	11
Amphiope sp. 2	a	3+11	14	8+8+	16	8+7	15	4+10	14	3+-		6+4	6+4+	4+9	5+9	6+5	11
MAC.PL552, Late Burdigalian	b	5+10	15	8+9	17	8+8	16	3+10	13	4+-		6+5	6+6+	4+9	4+9	6+4	10
Amph sp. 3 MAC.PL1669	a	3+10	13	6+7	13	7+7	14	4+11	15	3+10	13	5+4+	5+5	4+9	4+10	6+4	10
Serravallion - Tortonian	b	4+11	15	7+7	14	6+7	13	3+11	14	4+9	13	5+4	6+4	4+10	3+9	5+4	9
Sculpsitechinus tenuissimus	a	3+6		7+8	15	7+6	13	5+8	13+	4+9	13	5+6	6+(-)	4+(-)	5+(-)	6+-	
Recent	b	4+6		7+7	14	7+6	13	4+6	10+	5+10	15	6+(-)	6+(-)	5+(-)	4+(-)	6+-	
Sculpsitechinus auritus	a	4+10	14	7+7	14	7+7	14	5+11	15	4+10	14	6+6	6+6+	5+9	5+10	6+6	12
MAC.IVM87, Recent	b	5+10	15	7+8	15	6+7	13	4+11	14	5+10	15	7+5+	6+6	5+9	4+10	5+7	12
Sculpsitechinus sp. 1	a	4+11	15	7+7	14	7+8	15	5+11	16	4+10	14	6+6	6+7	4+10	5+11	6+6	12
MAC.IVM210, Recent	b	4+11	15	8+7	15	7+6	13	4+11	15	5+11	16	6+7	6+6	5+10	5+11	7+6	13
Echinodiscus andamanensis	a	3+9	12	5+6	11	5+5	10	4+8	12	4+8	12	5+5	5+5	5+9	4+6	6+5	11
Thailandia, Recent	b	3+9	12	5+5	10	5+5	10	5+8	13	4+8	12	6+4	6+4	4+9	4+5	6+6	12
Echinodiscus truncatus	a	3+10	13	6+6	12	6+4	10	4+10	14	3+9	12	5+6	5+5	4+8	4+8	5+5	10
Singapore, Recent	b	3+9	12	6+5	11	5+6	11	4+9	13	4+9	13	5+5	5+5	4+8	4+8	5+5	10
Echinodiscus bisperforatus	a	3+9	12	7+6	13	8+6	14	5+11	16	4+9	13	6+5	6+4	4+10	5+10	7+4	11
	b	4+9	13	8+5	13	7+6	13	4+10	14	4+10	14	6+5	6+4	4+10	5+10	7+4	11

Table 7. Number of plates in some Astriclypeids species. Ia = interambulacrum; Amb = ambulacrum;
Σ = summation of oral and aboral plates per column.

II. MAIN CHARACTERISTICS DISTINGUISHING *AMPHIOPE* FROM *ECHINODISCUS*

Durham (1955: 154, fig. a, b) and Smith & Kroh (2011) indicated some characteristics of the oral plating which distinguish *Amphiope* from *Echinodiscus*. In species belonging to *Amphiope* in the oral interambulacrum 5 there are two postbasicoronal plates in column a (2a, 3a) and three in column b (2b, 3b, 4b), with the plate 2b more elongated and staggered than the 2a and in amphiplacous contact with the first two adjacent postbasicoronals ambulacral plates (Fig. 8a). In species belonging to *Echinodiscus*, in the oral interambulacrum 5 there are two postbasicoronal plates per column in wich the first two plates 2b/2a are similar-sized and paired (Fig. 8b).

From Kroh (2005), Pereira (2010) and Stara & Borghi (2014), we have taken other characteristics that distinguish *Amphiope* from others genus. Since the shape of the lunules in *E. bisperforatus* is hardly distinctive, we found the other characters of this genus by a number of samples stored in a museum, how above documented.

In the aboral face of *Amphiope*, there are always one-two pairs of plates between the petal tips and the corresponding lunules and the plates surrounding the lunules are arranged in a radial manner (Plate 8 Figs. 1, 2; Plate 9 Figs. 1, 2; Plate 10 Figs. 1, 2). In the aboral face of *E. bisperforatus*, there
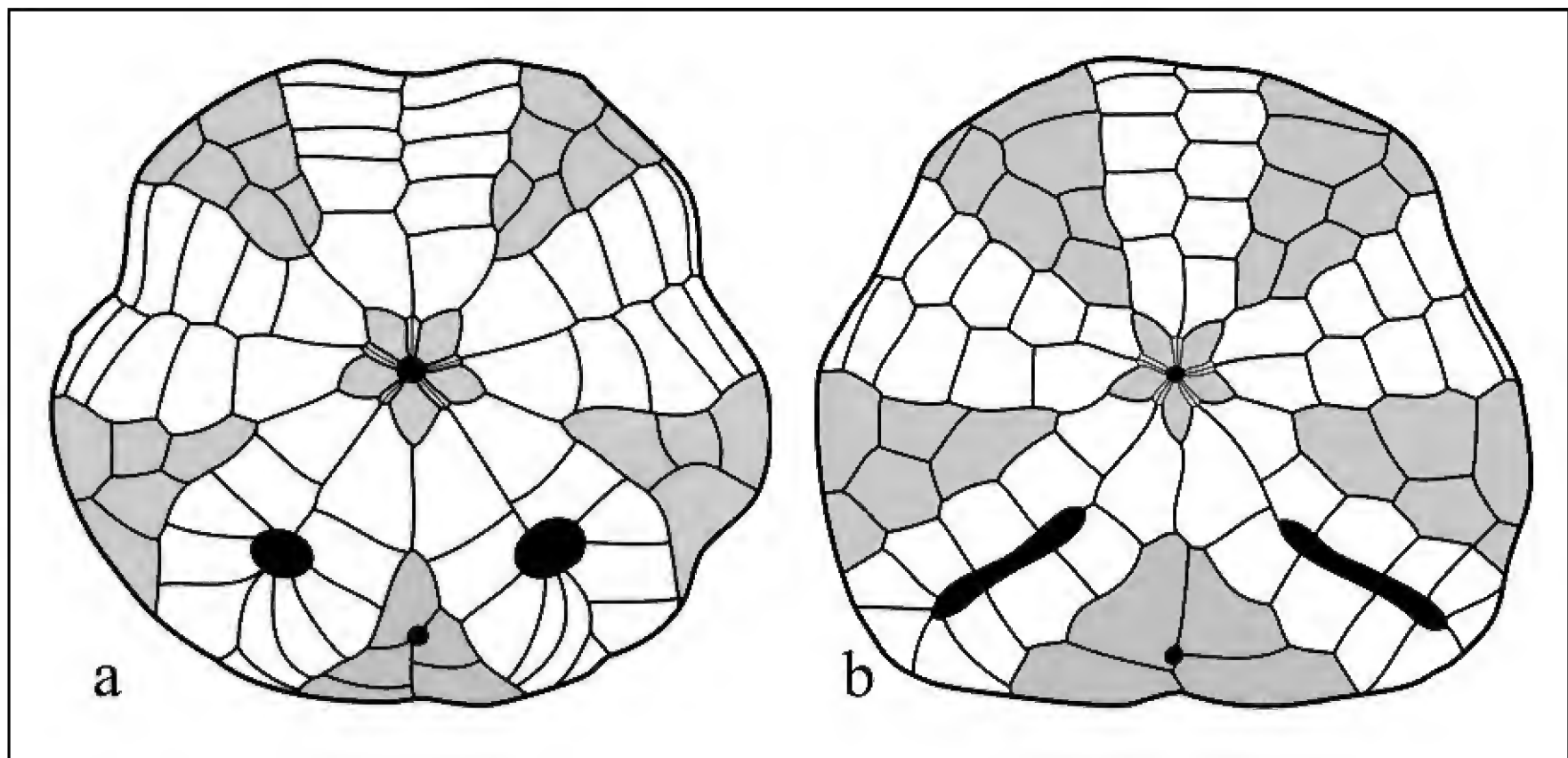
Figure 8. Plate patterns of adoral sides of *Amphiope* "*bioculata*" and *Echinodiscus bisperforatus* from Durham (1955: p. 154, figs. a, b) and Smith & Kroh (2011); in red the oral postbasicoronal interambulacral structures.
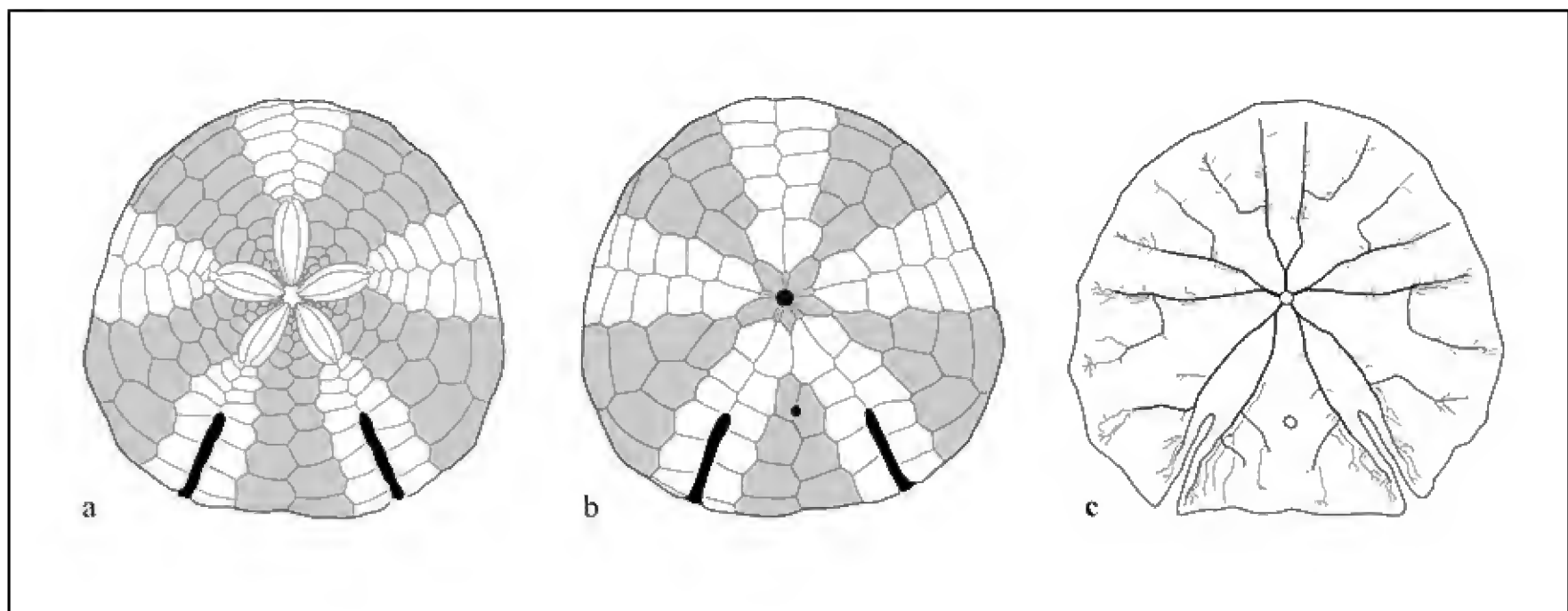
Figure 9. *Sculpsitechinus auritus* from Mangili (Recent, Tulear, Madagascar); a, b: respectively, aboral and oral plate structure of MAC.IVM 87; c: food grooves scheme.

are similarly one-two pairs of plates between the petal tip and the corresponding lunules, but the plates surrounding the lunules are arranged in a linear manner (Plate 9 Fig. 5). Finally, Smith & Kroh (2011), state that *Amphiope* have roundish-ovoid transverse lunules, while *Echinodiscus* have ovoidal axial lunules or notches.

Based on these characters, and others that have already been published in the pages of *Amphiope* and *Echinodiscus* genus in Smith & Kroh (2011), we have included in these genera the morphotypes

whose the plate patterns of interambulacrum 5, coincided with those described by Durham (1955) and Smith & Kroh (2011).

According to logic, the forms that do not match with any of the two types have been treated by us and characterized as belonging to several new genera. Then, in the following we will use the terms *Amphiope* and *Echinodiscus* to indicate any form of astriclypeids corresponding to the description summarized above.

DISCUSSION ON SYSTEMATICS ASPECT

The specimens of "*Echinodiscus auritus*" described by Stara & Fois (2014) do not match with the above reported concepts of *Echinodiscus* and *Amphiope*. The first two postbasicoronal plates 2b and 2a in the oral interambulacrum 5 are partially staggered and the total number of plates per column is higher (4 in column b and 3–4 in column a) than those of *Echinodiscus* and *Amphiope* (see Plate 10 by comparison). Also the couples of plates present between the tip of each petal and the corresponding notch is higher than those of *Echinodiscus* and *Amphiope* (see Plate 9).

Furthermore, the size of the petalodium (PL) is significantly lower than that of *Amphiope*, where as WA is lower than that of both genera. Even the complicate and dense food grooves branching is peculiar. Based on these characters this form is attributed to a new genus, *Sculpsitechinus* genus novum, The definition of the corresponding type species is reported in the following systematics chapter (see Figs. 9a–c).

The oral structure of the sample of "*Amphiope*" sp. from Channay-sur-Lathan (Plate 2 Fig. 6) matches the schemes published by Durham (1955), Pereira (2010), Smith & Kroh (2011) and Stara & Borghi (2014). The plate 2b of the interambulacrum 5 is longer and staggered with respect to the 2a; the lunules are more or less roundish and surrounded by plates arranged in a radial manner. The size of the lunules do not correspond to the samples from Sardinia (Stara & Borghi, 2014). It is clear that this form belongs to the genus *Amphiope*. However it is left in open nomenclature, *Amphiope* sp. 3, since the type species of *A. bioculata* Des Moulins, 1837 still needs definition.

Both the morphotypes recognised within the sample of "*Amphiope*" *pedemontana* Airaghi, 1901 have an oral plate structure corresponding to the plating pattern of *Echinodiscus* given by Durham (1955) and Smith & Kroh (2011). Also the axially elongate lunules and the plate arrangement around them indicate that they belong to the genus *Echinodiscus* (Figs. 2a–c).

The first morphotype corresponds to the original description and is herein assigned to *E. pedemontanus* (Airaghi, 1901). The other form is left in open nomenclature, *Echinodiscus* sp. 1, since only two are available to study and they are poorly preserved.

The specimens of "*Amphiope duffy*" Gregory, 1911, from Cyrenaica (Libya) (Plate 3 Figs. 1–6), show a plate structure in the aboral side which is quite different from the plate patterns of *Amphiope* and *Echinodiscus*. The arrangement of the plates surrounding the lunules is linear as in *Echinodiscus* but there are 3–4 couples of plates between the lunules and the corresponding petal tips. It is noticeable that one of the petals is open distally, as in *E. pedemontanus*. Since the oral plating of these echinoids is not visible, better preserved material is needed to clear the systematic position of this form.
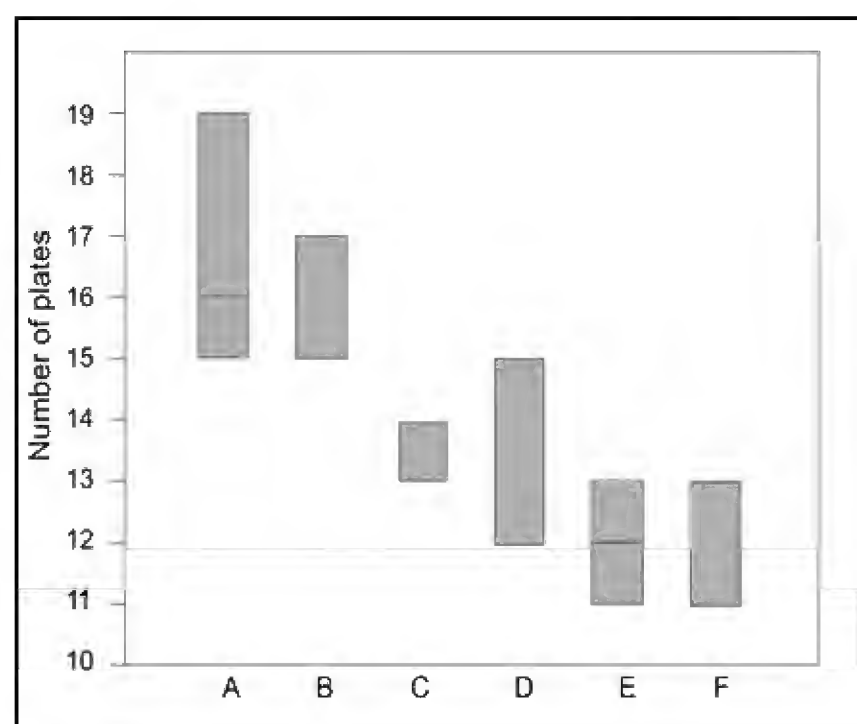
Figure 10. Numbers of post-basicoronal plates comparison in *Amphiope* from different geological age. A, B: *A. nuragica*, Oligo-Miocene, respectively inter. 5 and ambulacrum III. C, D: *Amphiope* sp. 2, Late Burdigalian, respectively inter. 5 and amb. III. E, F: *Amphiope* sp. 3, Late Serravallian, Tortonian, respectively, inter. 5 and amb. III.

The oral and aboral structures of the large sample of *E. bisperforatus* from various localities of the Indian Oceans and the Red Sea mach with the plating schemes given by Durham (1955), Jansen & Mooi (2011), Smith & Kroh (2011). It seems likely that different species may be present within the studied sample (Plate 4 Figs. 1–8; Plate 5 Figs. 1–3), however further studies are needed to clear the question.

Samples attributed to "*E. tenuissimus*" L. Agassiz, 1847. The first morphotype (Fig. 3a) has both the oral and aboral plate structure that does not match those of *E. bisperforatus* Leske, 1778, and is closer to "*E. auritus*" studied by Stara & M. Fois

(2014). The plates arrangement of the oral interambulacrum 5 and the number of couples of plates between the petal tips and the corresponding lunules is high and matches those of "*E. auritus*" (Fig. 9a, b). Also the particular branching of the food grooves matches with that of "*E. auritus*". Based on these observations this morphotype is placed into *Sculpsitehinus* n. gen.

Since the holotype of *E. tenuissimus*, from Waigiou, eastern Indonesia is wanting, a specimen from Lembeh, North Sulawesi (eastern Indonesia) is proposed as neotype of *Sculpsitechinus tenuissimus* (L. Agassiz, 1847) (Plate 11 Figs. 5, 6).

The second morphotype from Andaman Sea of Thailand, has the plating structures of oral and aboral faces that match with *Echinodiscus*, since in the oral interambulacrum 5 the postbasicoronal plates 2b and 2a are paired as well as 3b and 3a (Fig. 3b). Also the axial lunules and the structure of the plates surrounding them matches with those of *E. bisperforatus*.

This morphotype which is a true *Echinodiscus* and, given the differences between it and the other species of this genus, as we shall see in the chapter of the systematic, is here named *E. andamanensis* n. sp.

The third morfotype from Indonesia (Borneo), has the plating structure of the oral interambulacrum 5 with the two first postbasicoronal plates staggered as in *Amphiope* (Fig. 3 c), but it has the plate arrangement that encircling the lunules as in *Echinodiscus*.

It is evident, now, that this form belongs to a new genus. Therefore, we introduce *Paraamphiope* n. g., as it has some similarities with *Amphiope*. This morphotype is named *Paraamphiope raimondii* n. sp., after the collector who donated the specimen to our museum.

The specimens labeled *Echinodiscus truncatus* from Singapore, has a plate structure of the oral interambulacrum 5 that matches with that of *Echinodiscus* (see Fig. 4), but they differ from other species of *Echinodiscus* in many features, that make us consider this a true *E. truncatus* (L. Agassiz. 1841).

Also the specimen collected from Hurgada, Red Sea, shows the plate structure of the oral inter-ambulacrum 5 corresponding with that of *Echinodiscus* (Figs. 5a, b). They differs from *E. andamanensis* n. sp. and *E. truncatus* by the position of the periproct, that opens more rearmost, between the plates 2a/3b/3a. This is likely a different
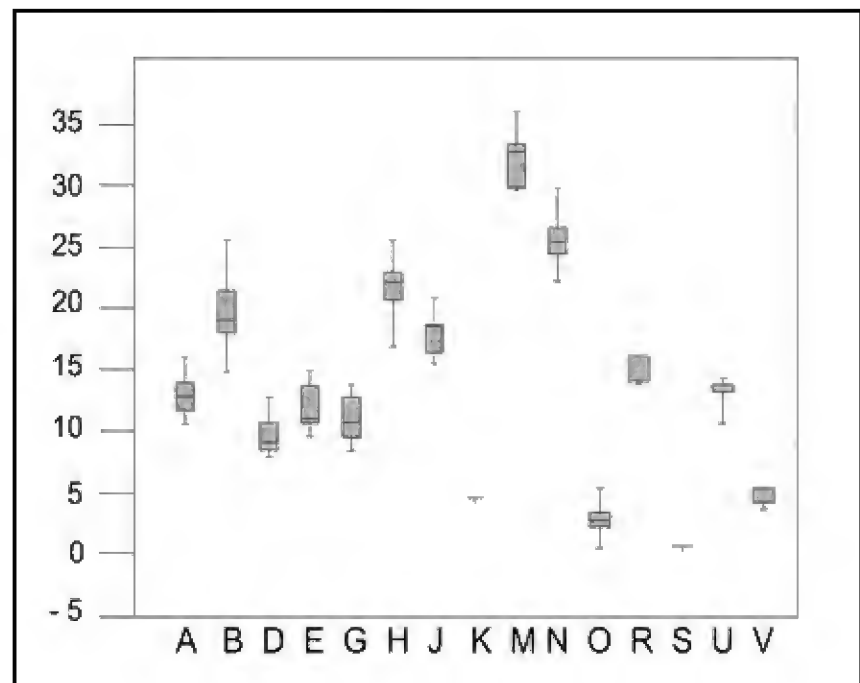
Figure 11. Comparison of lunules size variability in *Amphiope*, *Echinodiscus* and *Sculpsitechinus* species. A-B: respectively, L1 and L2 variability in *A. lovisatoi*. D, E: respectively, L1 and L2 variability in "*A. bioculata*" in Cottreau (1914). G, H: respectively, L1 and L2 variability in *A. nuragica*. J, K: respectively, L1 and L2 variability in *E. truncatus*. M, L1 variability in *E. bisperforatus*. N, O: respectively, L1 and L2 variability in *S. auritus*. R, S: respectively, L1 and L2 variability in *E. andamanensis* n. sp. U, V: respectively, L1 and L2 variability in *S. tenuissimus*.
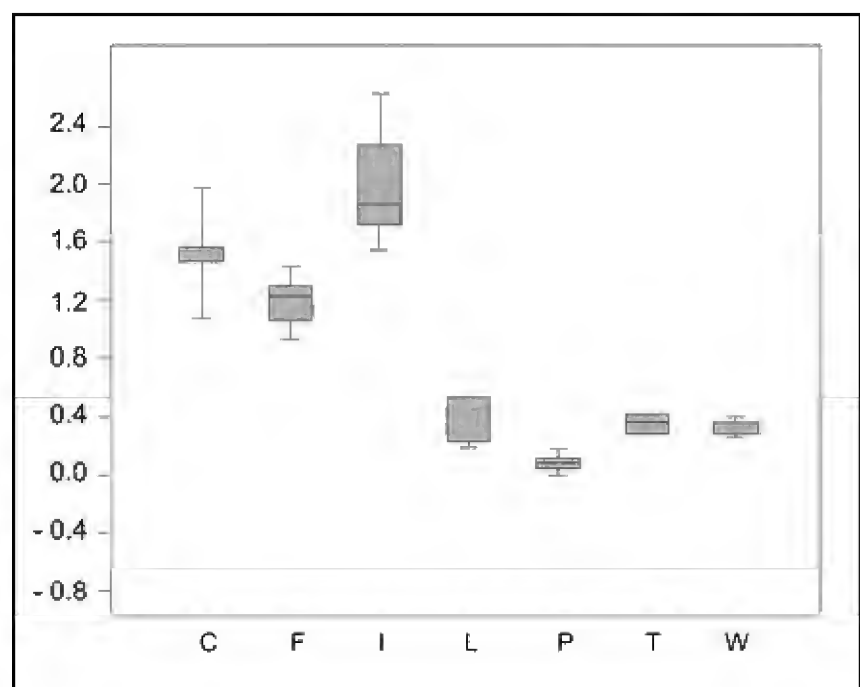
Figure 12. Comparison of differences and variability in lunules shape utilizing SI. C: *Amphiope lovisatoi*. F: "*A. bioculata*" in Cottreau (1914). I: *A. nuragica*. L: *Echinodiscus truncatus*. P: *Sculpsitechinus auritus*. T: *E. andamanensis* n. sp. W: *S. tenuissimus*.

species but, since the sole specimen available to study is poorly preserved, it is left in open nomenclature: *Echinodiscus* sp. 2.

The examined specimens of "*Amphiope*" *arcuata* Fuchs, 1882, from the "Miocene" of

Libya, has the oral plate structure on interambulacrum 5 (Fig. 2d) that matches with *Paraamphiope raimondii* n. sp. It differs by *P. raimondii* by greater distance between petal tips and lunules and by longer lunules. Based on these characters this form is attributed to *Paraamphiope* genus novum and assigned to *Paraamphiope arcuata* (Fuchs, 1882).

The specimens labeled as *Echinodiscus desori* Duncan et Sladen, 1883 are incomplete and the sole oral face visible is only partially legible. Using the available data, these echinoids probably belong to *Echinodiscus*, by the shape of the lunules and by the arrangement of the plates surrounding them (Plate 6 Figs. 1–6). Also the petals, clearly open distally, connect them to *E. pedemontanus*.

The sample of "*Amphiope bioculata*" des Moulins described by Cottreau (1914) (Plate 7 Figs. 1–11) likey belongs to the genus *Amphiope* L. Agassiz, 1840, by the large petalodium, that in some specimens gets up to 60% TL, the roundish lunules with a SI value of about 1.5, and the distance of the lunules from the tips of the petals which is very short. However, it is not possible to attribute these specimens to *A. bioculata*, since their plate structure was not reported by Cottreau (1914) and, on the other hand, the type species of *Amphiope* still needs defining.

The "*Lobophora aurita*" illustrated by L. Agassiz 1840 (Fig. 6), clearly belongs to the *Sculpsitechinus* n. gen., by the plate structures, close to that of *S. auritus* (Leske, 1778) and *S. tenuissimus* (L. Agassiz, 1847) (see Plate 11 by comparison). The oral interambulacrum 5 has 4 couples of postbasicornal plates, with 2b and 2a partially staggered and low WA value. There are six couples of plates between the petal tips and the corresponding notches and the PL is very small. It differs from the above mentioned species by the periproct that opens between plates 3a and 3b.

Since the original specimen is wanting, this species is left in open nomenclature: *Sculpsitechinus* sp. The species *E. formosus, E. yeliuensis, E. cikezenensis* and *E. transiens* were based on specimens with the oral face covered by sediments. Lacking the important characters of the oral face, such as the interambulacral plating, a comparison with the type species *E. bisperforatus* is unreliable.

For any other consideration see the conclusions chapter.

DISCUSSION ON MORPHOMETRIC AND MORPHOLOGICAL ASPECTS

In the following some relevant characters and morphometric values highlighted by the studies of Stara & Fois (2014) and Stara & Borghi (2014) are compared with the results of this study. This can be useful for further studies to improve the knowledge of this interesting family of echinoids.

The sample of *Amphiope* examined by Stara & Borghi (2014) and in this work, represents a time span that ranges from the Chattian-Aquitanian to the Serravallian-Tortonian (about 13–14 Ma). Furthermore, this sample confirms what has been observed by Stara & Borghi (2014): in the echinoids belonging to this family, during the geologic time, there was a downward trend with a decreasing total number of plates. The sample examined in this study also includes other genera of astriclypeids like *Echinodiscus*, which are present from Rupelian to Recent, *Paraamphiope*, which runs from the middle Miocene to the present and *Sculpsitechinus* that may have been present in the Miocene and is very wide spread in the Recent.

Durham (1955) noted that the number of plates on the oral face is fixed at the end of metamorphosis, whereas some new plates are formed in the aboral face during the early stages of growth (e.g. from 2-3 mm to 10–15 mm TL). No significant variation in the total number of plates per column was observed by Durham on both oral and aboral faces of the examined adult individuals (TL = 50 to 62 mm).

The same result emerges also from the available sample of *Sculpsitechinus auritus* (former *E. auritus*) from Mangili, consisting of about thirty specimens with TL ranging from about 70 mm to 150 mm (see Stara & Fois M., 2014). Smith (2005) confirmed that the number of plates in adult clypeasteroids remains almost unchanged during the stages of growth in this group of echinoids (see Fig. 10).

In samples of *Amphiope*, on the other hand, we can see one particularity: there is a decrease in the overall plate number as a consequence of the "geological age". Kier (1982) noted that there was a trend within cassiduloids for a decrease in the number of plates through time, and this may reflect a general trend towards fewer and earlier formed plates (from Smith, 2005).

We can deduce that the *Amphiope* with greater number of plates is more archaic than that with

lower number of plates. It would be logical that this should also be observed in "*Echinodiscus*", but it is not obvious, in part due to the heterogeneity of the treated samples, which look more like a paraphyletic group than a monophyletic one, and in part due to the presence of too many gaps in the fossil records.

On the variability in size and shape of the lunule/notches

From the comparison between the samples examined, we observed that lunules are variable in shape and in dimension, and that the greater variability seems to affect only some species and some populations.

The sample utilized by Cottreau (1914) seems to show the largest variability range of the lunules (variance), which is respectively 49% on L1 average and the 45% on L2 average; the other samples decidedly show a lower variability, which ranges between 22% in *E. bisperforatus* and 41% in *Paraamphiope arcuata*.

Moreover, the finding of distorted lunules has been the normality, as noted by Stara & Borghi (2014) on over 100 complete specimens of *Amphiope* from Sardinia and many fragments with lunules belonging to different species and localities, and this can often make worthless the measures.

Comparing in a graph the size of L1 and L2, detected in a larger sample [40 specimens of *A. lovisatoi* (data from Stara & Borghi, 2014); 11 "*A. bioculata*" in Cottreau; 25 *A. nuragica*] however, we see that the sample of Cottreau's "*Amphiope*" is not the more variable, but that the more variable is *A. lovisatoi* from Sardinia. The graph (Fig. 11) shows that, despite the significant variability in the size of lunules, remain clear the specific differences (see in particular the difference between "*A. bioculata*" in Cottreau and *A. nuragica*).

Using the SI and WI data, in "*A. bioculata*" in Cottreau, SI range from 0.95 to 1.47 (mean 1.22) (Table 6); in *A. nuragica* the SI range from 2 to 3 (mean 2.4). As demonstrated (see Table 8), this system highlights the real differences very well.

Now, if we compare the SI of the various samples utilized in the first graph (Fig. 11), the specific differences between *A. lovisatoi*, "*A. bioculata*" and *A. nuragica* become very evident, (Fig. 12 C, F and I). About the samples of the other genera (*Echinodiscus* and *Sculpsitechinus*), instead, it is seen that the vari-
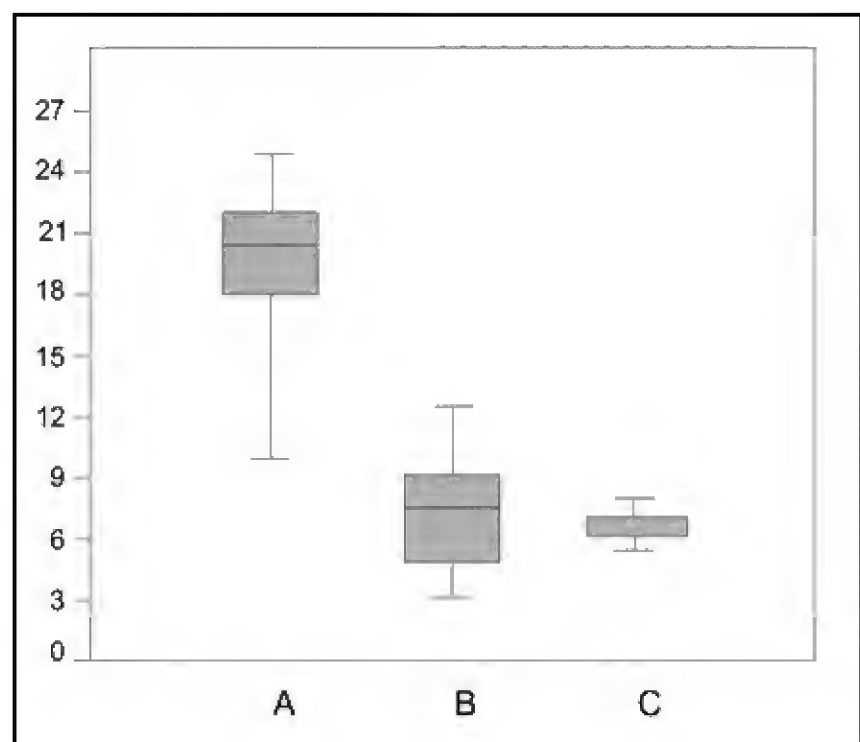
Figure 13. L11 comparison, respectively with *Sculpsitechinus* species (A), *Echinodiscus bisperforatus* group (B) and others *Echinodiscus* (C).

ability of lunules is much lower and the specific difference is highlighted much more through the measurement of L1 and L2 (see Fig. 11, samples J–V).

Finally, the lunules variability exists, but this does not make difficult to specific distinction. Indeed, it is demonstrated that the shape of the lunes (measured with the SI) becomes really distinctive between species.

On the plates arrangement encircling lunules/notches

The position of the lunules along the ambulacrum has visibly changed during time, but we can evaluate this change in the oldest species only partially, given that in most of the literature only the aboral face is shown and is sometimes incomplete.

Now, there are at least two possibilities: different starting point or finishing point of the lunules, and different number of couples of plates surrounding the lunula in the oral and aboral side.

As noted by Stara & Borghi (2014) the number of couples of plates that surround the lunules can vary greatly from species to species, and in particular look different between geologically younger species from geologically older ones.

In *Amphiope* from Chattian-Early Aquitanian from Cuccuru Tuvullao, the couples of plates that encircle aborally the lunules are 8–9, while in the oral face are 4–4 (about half); in the specimens
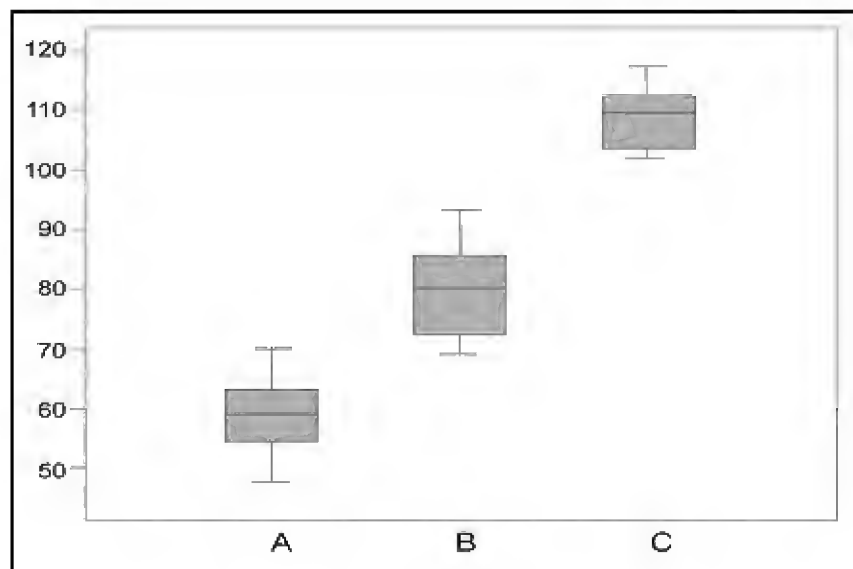
Figure 14. ß angle comparison, respectively with: S*culp-sitechinus* species (A), *Echinodiscus andamanensis* n. sp., *E. truncatus*, *Echinodiscus* sp. 1, *Echinodiscus* sp. 2 (B), and *E. bisperforatus* group (C).
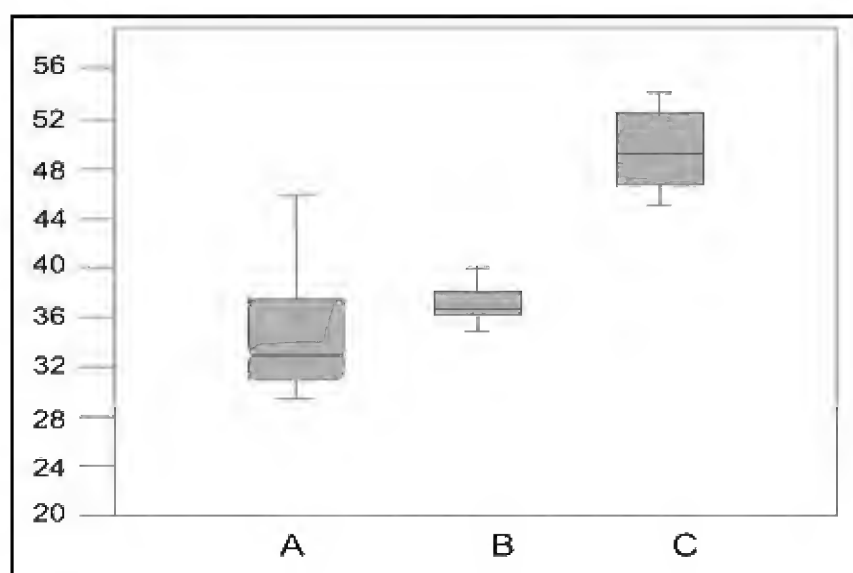
Figure 15. Wa comparison, respectively, with: *Sculpsitechinus* species (A), *Echinodiscus* and *Paraamphiope* species (B), and *Echinodiscus bisperforatus* group (C).
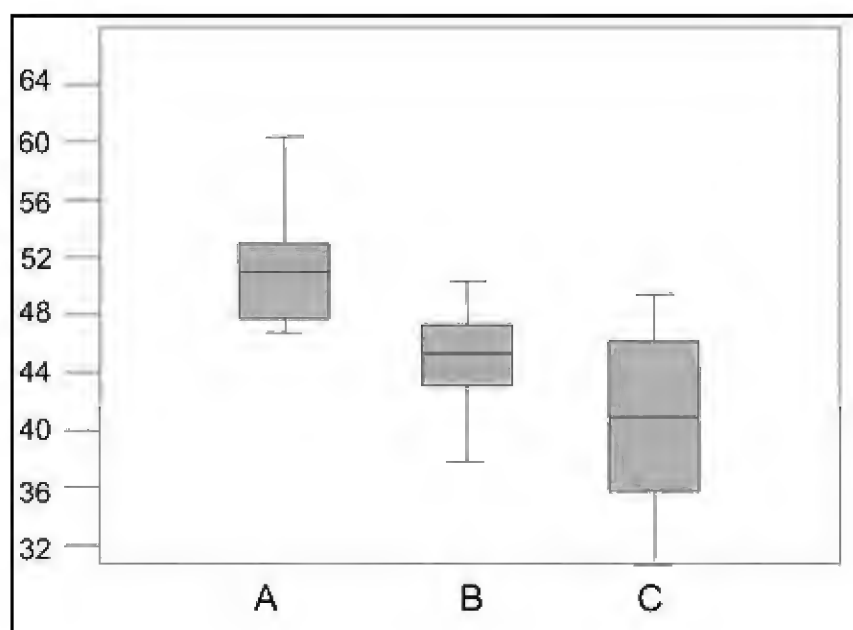
Figure 16. PL comparison, respectively, with: *Amphiope* species (A), *Echinodiscus* and *Paraamphiope* species (B), and *Sculpsitechinus* species (C).

from Channay-sur-Lathan the situation is 6–6 against 3–4, with an aboral/adoral ratio sharply decreasing.

In *E. pedemontanus* the couples of plates on aboral side ranges among 4–5 and 5–6; in the adoral side, however, they range from 2–2 to 3–3. It seems clear that the more archaic characteristics (greater number of plates) are located in *A. nuragica* (Co-maschi-Caria, 1955), so this last one can not descend from *E. pedemontanus*, but could derive from a more archaic ancestor.

In other *Echinodiscus* fossils, we can observe the following: in *E. cikuzenensis*, on aboral side, the couples of plates are 6–6, the highest number between the fossils of their genus, but we do not know the number of the corresponding adoral ones (assuming that they are 8, the highest number known, the total number will be 14 plates per column, very far from the 16–20 of *A. nuragica*).

On the other hand, *E. bisperforatus* shows more plates than *E. andamanensis* n. sp., which has the lowest number of plates of all (see Table 6).

In all samples of *Amphiope*, between the lunules and the corresponding petal tips there are one or two pairs of plates (not occluded); while on the oral side the lunules begin constantly from the second pair of the post-basicoronal plates.(see Plate 9 Figs. 1, 2; Plate 10 Figs. 1, 2)

In *E. pedemontanus* there are 3–4 couples of plates between lunules and the corresponding petals tip, as in *Paraamphiope arcuata*.

Summarizing, in other forms of *Echinodiscus*, excluding *E. bisperforatus*, between the petal tip and the corresponding lunula/notch there are two-three pairs of plates (Plate 9 Fig. 4), and these are arranged in a linear manner, as in *E. bisperforatus*. Therefore these characteristics seem constant and diagnostic and in the future it will be necessary to take them into account. For more information see the respective plates and the plate patterns reported in plates 9, 10.

Migration of the periproct

The migration of the periproct is one of the main evolutionary processes of irregular echinoids (Durham, 1955; Kier, 1982); from the apical disc the periproct migrates towards the peristoma, viz, from the aboral surface shifts to the oral one. Echinoids of this family always have the periproct in the oral

face, between the peristome and the ambitus and it is clear that the periproct does not change its position with respect to individual plates after those plates have started to form, at the end of the metamorphosis, except for occasional cases (Durham, 1955).

But with the passing of geological time, its position is not fixed and immutable, nor is the plating that surrounds it. Thus, the "migration" of the periproct occurs simultaneously with changes in the plating and width of the plates, and in the internal structure, too. We noticed plate pattern modifications, that we believe to be diagnostic, as well as an increase or decrease in number, or breadth and shape changes, of the post-basicoronal interambulacral plates on inter. 5 and on the ambulacra I and V.

Considering the *A. nuragica, Amphiope* sp. 2 (in Stara & Borghi, 2014) and *Amphiope* sp. 3 series, which covers a Chattian-Aquitanian to Serravallian-Tortonian time-span, the position of the periproct to the relative plates seems to be indicative to the effect of time and evolution; indeed, the distance from the posterior margin has even decreased (L11 varies from a minimum of 10% of TL in *A. nuragica* to 4% TL in *Amphiope* sp. 3) simultaneously to the decreasing in size of the last echinoids.

In *A. nuragica* sample the periproct position relative to the plates is very variable; and this last one may open both between the plates closest to the rear edge (3a/4b), both between the most anterior ones (2a/3b), never between 2b/2a. We also noted that in this archaic form, the periproct position with respect to the related plates and their number, appear very inconstant, unlike the most recent forms.

In the sample of *Amphiope* sp. 2 the position-plates ratio is more steady, so the periproct always opens between plates 2a/3b, as in *Amphiope* sp. 3. However, in Cuccuru Tuvullao outcrop one can also find the morphotype with predominantly transverse lunules, *Amphiope* sp. 1 (see Stara & Borghi, 2014), with the periproct opened along the suture between the first two plates 2b/2a. This could indicate a convergent evolution of two close species, evolved at different speeds and in different environments, and probably found themselves in the same locality only by accident (in a slightly different times).

This last situation may depend on the well differentiated Oligo-Miocene faunas, and on the incomplete scene of the previous evolutionary steps, due to the fossil record gaps. Perhaps it will be

Sample	range SI	mean SI	range WI	mean WI	Variance L1	Variance L2
Amphiope bioculata. in Cottreau. 1914	0.95 ÷ 1.47	1.22	9 ÷ 12.5	10.20	49.2	45.4
Amphiope nuragica	2 ÷ 3	2.4	11.5 ÷ 15	13.5	36	22
Amphiope sp. 2	1.2 ÷ 1.5	1.3	11 ÷ 16	13	36	27
Amphiope sp. 3	1 ÷ 1.6	1.26	9 ÷ 10.5	9.8	34	27
Echinodiscus pedemontanus	0.26 ÷ 0.54	0.37	9.2 ÷ 11.2	10.4	--	--
Paraamphiope arcuata	0.45 ÷ 0.76	0.63	8 ÷ 10.5	9.3	36	41
Sculpsitechinus sp. 1	--		--		34	--
Sculpsitechinus auritus	--		--		29	--
Echinodiscus bisperforatus	--		--		20	--

Table 8. Comparison of index and data variation, between *Amphiope* samples and other astriclypeids genera.

possible to answer to this question by furthering studies on the structure of the samples from Provence and the Bay of Biscay ones.

In samples of *Sculpsitechinus* from Mangili and from Philippines the periproct always opens along the suture between the post-basicoronal plates 2b/2a, while in the specimen from the Red Sea, illustrated by L. Agassiz (1840: pl. 14 fig. 2) and reproduced here in figure 6, it opens in the rearmost position, between the plates 3b/3a.

In the group of living *Echinodiscus andamanensis* n. sp., *E. truncatus* and *E. bisperforatus*, the periproct opens along the suture between the plates 2a/2b or at the junction 2a/2b/3b. In any case, these forms differ from the *Sculpsitechinus* "group" in which the periproct-posterior margin distance and the plates number on the inter. 5 is higher. In fact, within this group of living echinoids, the periproct distance (L11) varies from 11 to 25% TL, within a plating with more plates per column in interambulacrum 5 (2–3 in column "a" and 4–4 in column "b").

Plates number and shape on the interambulacrum 5 and periproct position

In plate 10 are summarized the results of our observations about these characteristics. Highlighting the diversity in the genera there are three platings. The distance between the periproct from the rear edge, its position along the perradial suture in the inter. 5, the shape and the relationship established between the various plates that form in particular the inter. 5 and the ambulacra I and V, seem highly diagnostic at the level of genus and species.

The distance of the periproct from the posterior margin is a characteristic which is considered to be very important by ancient authors. As we have already seen, its position is partially related to the arrangement, shape and size of the plates of the inter. 5. However, for the same plating, the distance may be diagnostic for the species, if it is confirmed by statistically significant numbers. Here we simply report what, in general, has been detected in the small samples which we examined (Fig. 13).

Angle β and WA

Given that rounded lunules can not show angles with respect to the corresponding petal, the problem could be solved only studying the morphotypes with elongated lunules and in particular those elongated axially. In particular, the ß angle seem very significant; important data are drawn by the quantification of this peculiar situation in tables 9. These data highlight different groups, corresponding to different species and / or genera, and in particular highlight *Sculpsitechinus* (ß = 55° to 67°), *Echinodiscus* and *Paraamphiope* (ß = 70° to 85°) and *E. bisperforatus* (ß = 105° to 111°).

A characteristic which, up until now has been underestimated, is the size at the ambitus of the various ambulacral and interambulacral sectors. In particular, the WA at interambulacrum 5 appears to be very important, seeing it differentiates two of the genus studied by us: *Echinodiscus* and *Sculpsitechinus*. Furthermore, the *E. bisperforatus* group differentiates itself from the other.

Petalodium

One of the important aspects in these echinoids is the petalodium length (PL), which can be very different from group to group. In this comparison we considered a total of 54 specimens of *Amphiope*, according to the table 10. On the specimens from 11 different Sardinian localities (see also Stara & Borghi, 2014), the PL size ranges from 47 to 57% TL (mean 52 N42). In the totality of the specimens from Italy, Spain, France and Iran, the dimensions range from 45 to 60% TL (see Plate 8 Fig. 1), with the majority between 48 and 53%. In the sample of *Sculpsitehinus auritus* from Mangili in Stara & Fois (2014) PL is 34–45% TL, as in the sample of *S. tenuissimus* (29–45% TL) (see Plate 9 Fig. 8).

In *E. bisperforatus* PL is very variable, reaching from 40 to 52% TL. In this species, the front odd petal is always longer than the rear ones, which are always decidedly shorter. The size of the remaining "*Echinodiscus*" is very diversified and difficult to interpret, given the scarcity of the material available.

Another interesting feature is the presence of open petals in different species. In particular in *E. pedemontanus* the petals are all open. Some open petals are visible, however, also in *E. desori*, "*Amphiope*" *duffi* and, occasionally, even in *E. bisperforatus* (Fig. 16).

Sample	PL	WA	WA - range	ß	ß - range
Amphiope nuragica	49 - 53	42	38 - 46	--	--
A. sp. 2	50 - 54	38	37 - 40	--	--
A. sp. 3	50 - 53	32	29 - 36	--	--
A. bioculata in Cottreau, 1914	48 - 54	--	--	--	--
Sculpsitechinus sp. 1	41 - 48	33	30 - 38	57°	54 - 59°
Sculpsitechinus tulearensis	36 - 47	32	29 - 37	55°	48 - 62°
Scupsitechinus auritus	35	31	28 - 34	55	51 - 59°
Sculpsitechinus tenuissimus	30 - 45	32	31 - 35	67°	65 - 70°
Paraamphiope arcuata	42 - 46	31	33 - 35	85°	75 - 100°
Paraamphiope raimondii	47	38		80°	
Echinodiscus desori (India)	46 - 48	33	30 - 35	71°	68 - 74°
"Amphiope" Duffi	47	23		65°	
Echinodiscus pedemontanus	40 - 44	36	35 - 37	85°	73 - 93°
Echinodiscus sp. 1	44 - 46	37		69°	70 - 87°
Echinodiscus sp. 2	44	—		80°	
E. andamanensis	45.5 - 53	38	37 - 38	75.5°	68 - 85°
E. cikuzenensis	44	--		73°	
E. bisperforatus (Red Sea)	38 - 47	48	46 - 54	105°	102 - 110°
E. bisperforatus (S.Africa)	43 - 50	49	45 - 53	107°	102 - 117°
E. bisperforatus (Tanzania)	43	49		111°	
E. formosus		50		111°	
E. Jeliuensis	52?	34		114°	
E. transiens	52	--		--	

Table 9. Comparison of PL, WA and ß range data in a large sample of astriclypeids. ß in degree, other measures in % TL.

Amphiope (Sardinia, Italy)	47-57	52 N42
Amphiope (Alicante, Spagna)	48-51	49 N2
Amphiope (Channay-sur-Lathan, France)	51-53	53 N10
Amphiope bioculata in Cottreau, 1914	48-55	50 N11
Amphiope serasini (France)		50
Amphiope deydieri (France)		48
Amphiope baquiei (France)		48
Amphiope elliptica (France)		52
Amphiope hollandei (Corsica)		52
Amphiope cf. *bioculata* (Iran)		60

Table 10. Comparison of PL data in a large sample of *Amphiope*. Data in % TL.

Variability of the disjunction/contact between basicoronal and post-basicoronal plates

Random disjunctions between the basicoronal interambulacral plates and the related post basicoronal ones can be observed in many samples. For example, *Sculpsitechinus tenuissimus* from New Caledonia, *S. auritus* from the Red Sea and from Tulear, Madagascar, *E. bisperforatus* from Eastern Africa (see Jansen & Mooi, 2011) have high variability. The problem has already been studied by Durham (1955), who pointed out that more archaic scutellids show the basicoronal plates in contact with the following postbasicoronals, and that the separation is observable only in the most recent genera. He also noted that in *Dendraster excentricus* (Eschscholtz, 1831) from the Pacific coast of United States, juvenile individuals shown the basicoronal plates in full contact with the following ones. Furthermore, during growth, the second plate of each ambulacra grew faster than the others until its

separation from the second interambulacral ones, as indeed is observed in most representatives of the Astriclypeidae family.

Of all the species studied by Durham where this variation occurred, *Echinarachnius* showed the largest variability. Lohavanjiaya & Swan (1965) also studied this problem in more detail on some populations of *Echinarachnius parma* (Lamarck, 1816) from the coasts of New Hampshire (USA). These authors noted that there was a wide variability in the loss of contact between the basicoronal interambulacral plates and the corresponding post-basicoronal ones for each column, but it also varied the amphiplacous or meridoplacous conditions of the contact, when it was present. It demonstrated that the variation in the number of plates involved in the phenomenon followed individuals growth (size increase), and conceived that the phenomenon was caused by a selective response to genetically-induced modifications, at least partially, by different environmental factors for the different places where the tested samples lived. As for Durham's observations, we believe as normal (not diagnostic) the presence of basicoronal interambulacral plates in contact with the following post-basicoronal ones.

From the results obtained in particular from Stara & Fois M. (2014) on the sample of *Sculpsitechinus auritus* (Former *Echinodiscus* cf. *auritus*) from Mangili it is clear that the disjunction between the basicoronal and post-basicoronal plates in Inter. 5 is constant, but also that there is no constancy in disjunctions between the corresponding plates in other interambulacra (see Plate 5 Figs. 3–5). Moreover, from what emerges from the analysis of our sample, but especially from the sample (about 100 specimens) observed by Stara & Borghi (2014) were not basicoronal interambulacral plates in contact joint in *Amphiope*.

Differences in internal structure

As we have seen in the tested sample, while the morphology of these two groups of astriclypeids may be similar, the difference in the internal structures can be substantial. All groups have a single central visceral hollow with peripheral walls and pillars, but the floor reinforcement systems of the central cavity are profoundly different.

In *Sculpsitechinus* the floor is supported by a dense network of thin trabeculae or ribs (see Stara

& Fois M., 2014: pl. 2 fig. 7; pl. 4 figs. 6, 7), whereas in *Amphiope* the floor is supported by a system of thick masses, with appearance of callosity, modeled in different shapes depending on the species (see Plate 2 Figs. 2–4). Also the floor of the central cavity of *Parascutella* (personal observation) (but also of *Astriclypeus*) seems to have the same floor support structure that characterize *Amphiope* species.

Instead, the ballast system of all the astriclypeids is crossed by a different number of cavities more or less large, and by several micro-channels, which are distributed differently. A characteristic that does not appear to have been recognized enough so far is the size of Aristotle's lantern.

In percentage, the Aristotle's lantern is much larger in *Sculpsitechinus* sample from the Philippines than in the sample from Mangili, Madagascar (see pl. 6 in Stara & Fois, 2014).

However, some results obtained so far are very interesting. For example, the size of the Aristotle's lantern in *Paraamphiope raimondii* n. sp. is very large [27% of TL in a central hollow that measure 46% TL(Plate 19 Fig. 6) if compared to the 15–18% TL that characterize the Aristotle's lantern of *S. auritus* from Mangili (see Plate 23 Fig. 4) or the 15% TL of the Aristotle's lantern of *Sculpsitechinus tenuissimus* from Lembeh.

Other peculiarities

In *Amphiope*, the food grooves are always simple (Plate 1 Fig. 7), while they are always more or less branched in *Echinodiscus* and largely branched in *Sculpsitechinus* (Plate 22 Fig. 4).

INFLUENCE OF PALEOGEOGRAPHY DURING EOCENE-MIOCENE

Stara & Rizzo (2014), hypothesized that the Oligocene closure of the pre-Pyrenean corridor caused a separation (or the exchanges decreasing) between the North-Western Atlantic faunas and the Mediterranean ones. To understand the consequences of this, we need to study the evolutionary course of these faunas, in particular on the basis of the structural aspects.

From initial observations it appears that already in the late Rupelian-Early Chattian the scutellids

faunas of the Bay of Biscay were well differentiated. Even the "*Amphiope*" bearing axial lunules from Rupelian of Val Bormida had at least two morphotypes (Stara & Rizzo, 2013; 2014). In Early Miocene, the Rhône Basin was inhabited by "*Amphiope*" *boulei* Cottreau, 1914, a particular morphotype with small ellipsoidal axial lunules positioned far from their petals (Plate 14 Fig. 1); also during the middle Miocene, in Libya a similar morphotype appeared characterized by smaller and rounded lunules positioned far from the petals tip (Plate 14 Fig. 2). At the same time in India, *Echinodiscus desori* lived together *E. placenta* Duncan et Sladen, 1883, a form characterized by ellipsoidal axial lunules far away from the corresponding petals tip (Plate 14 Fig. 3). During Middle Miocene in Papua New Guinea lived another similar form, with long and narrow lunules (comparable with those of *Sculpsitechinus tenuissimus* (Plate 14 Fig. 4). Other morphotypes not appear so clear, as the "*Echinodiscus*" sp. from Miocene of Libya (Plate 14 Fig. 6), which has lunules open posteriorly, resembling the Recent *Sculpsitechinus auritus*.

Even *Amphiope* with rounded or transverse lunules was already well-differentiated, and widespread: this morphotype is found in the Bay of Biscay, in the Rhône basin, in central Sardinia and in the Kabylies.

Stara & Borghi (2014) found two different species of *Amphiope* with transverse lunules, both originating from Cuccuru Tuvullao, Sardinia, Chattian-Aquitanian in age: *Amphiope nuragica*, and *Amphiope* sp. 1. Not far from this locality (both from the spatial and temporal point of view), in the localities of Duidduru, Bruncu Montravigu Nuraghe Caiu and Tanca Sierra, also a form characterized by rounded lunules (Stara et al., 2012) was present.

To complete our knowledge of the differentiations occurred between the Biscay faunas and those of the Proto-Western Mediterranean, it will be necessary to know the structure of "*Amphiope*" *agassizi* from Middle Oligocene, and *A. ovalifora* from the Aquitanian of the Atlantic coast, and furthermore "*A.*" *boulei* from the Rhône basin. Given the wide temporal and the spatial distribution of *Amphiope*, as previously described, it is probable that numerous speciation events occurred even in different French regions, as occurred in Sardinia.

EVOLUTIONARY TRENDS

Now, as proposed by Cottreau (1914), *Amphiope* would be descended from some Atlantic-European "*Echinodiscus*", deriving also from *E. formosus*, because this last might be geologically the oldest. But the situation seems more complex and the current phylogenetic tree needs to be reviewed. Obviously, this requires a careful study of cladistics, and so for now we will only formulate hypotheses based on observations arising from this work.

Echinodiscus formosus from ?Middle Eocene and *E. yeliuensis* from Early Miocene of Taiwan, already had some features comparable to those of the living *E. bisperforatus* (e.g. a similar ß angle). This character and the lack of similar forms in the Oligo-Miocene peri-Mediterranean basins, suggest that this morphotype is derived from ancient faunas of the China Sea. But that does not seem true for other forms of *Echinodiscus*.

On the other hand, other common features such as the lunules shape and their distance from the corresponding petals, seem to connect "*Amphiope*" *boulei*, "*Echinodiscus*" *placenta*, ecc. (see Plate 14) to the group of *Sculpsitechinus*.

To clarify the relationship between the four groups which have emerged from this study (*Amphiope*, *Echinodiscus*, *Paraamphiope* and *Sculpsitechinus*), it is necessary to study more the internal structure of the various fossil forms of the far east and those that linked the north American faunas to the European ones.

It seems clear, however, that this trend has led to the current situation, in which we can see that, while *S. auritus* is spread throughout the Indian Ocean to the islands of the Western Pacific, the form *S. tenuissimus* seems confined to the Western Pacific (see Fig. 17). In these two forms, however, may also be included various species which only by new studies, based on more consistent sampling and analysis of pedicellaria and / or DNA, can be distinguished.

Among others, the most widespread form of *Echinodiscus* remains *E. bisperforatus*, while other forms seem very localized in restricted areas (see *E. andamanensis* n. sp. in the Andaman Sea and *E. truncatus* in the Singapore coasts). Even in this case, new studies, in part based on the analysis of the structure but also (for the living species) on other analysis, may better clarify their distribution areas.

For now, in figure 17 you can see the distribution areas of living forms so far recognized in this work.

OLD AND NEW PHYLOGENETIC HYPOTHESES

From the phylogenetic point of view, although several aspects still remain unclear, today we can say with reasonable certainty that in the dispute between Stefanini (1912) and Cottreau (1914) both had a share of reason. In fact, the thesis supported by Stefanini (1912) (he thought astriclypeids bearing axial lunules were real *Echinodiscus* and not *Amphiope*) is here confirmed for *E. pedemontanus* (former *A. pedemontana*).

However, as argued by Cottreau, the ancestor of "*A.*" *boulei* could also be the "*Amphiope*" with small axial lunules positioned far from their petals tips [such as "*Amphiope*" sp., from the Libyan desert (Plate 14 Fig. 2) and such *E. placenta* from India (Plate 14 Fig. 3]. We partially agree with him when he states that the living *Sculpsitechinus auritus* (former *Echinodiscus* cf. *auritus*) that colonized the entire Indo-Pacific area, could be derived from these echinoids. In fact, if we compare morphology and distance lunules-petals in these echinoids, with the one detectable in "*E. bisperforatus*" from Papua New Guinea (Lindley, 2001) (Plate 14 Fig. 4) and *S. tenuissimus* from Lembeh North Sulawesi and other East Pacific locality, (Plates 21, 22), we will see that they are relatively overlapping. We do not agree with Cottreau, however, when we examine the oldest *E. formosus* and *E. yeliuensis* from Taiwan. In fact, ß angle and distance between lunules and respective petals tips, seem to suggest them as being the ancestors of the living *E. bisperforatus*.

The fact that some features (shape of the plates in inter. 5 and the periproct position, etc...) accost them very closely to the *E. pedemontanus*, let us assume at least two possibilities. First presumes that already during the Middle Eocene these astriclypeids were very diversified and spread along the shores from the Atlantic to the China Sea; second, however, one presumes that from a single common ancestor who lived in the northern basins of the Atlantic Ocean during the Eocene, two forms detached. These last ones migrated then in opposite directions: one towards the inland basins of the
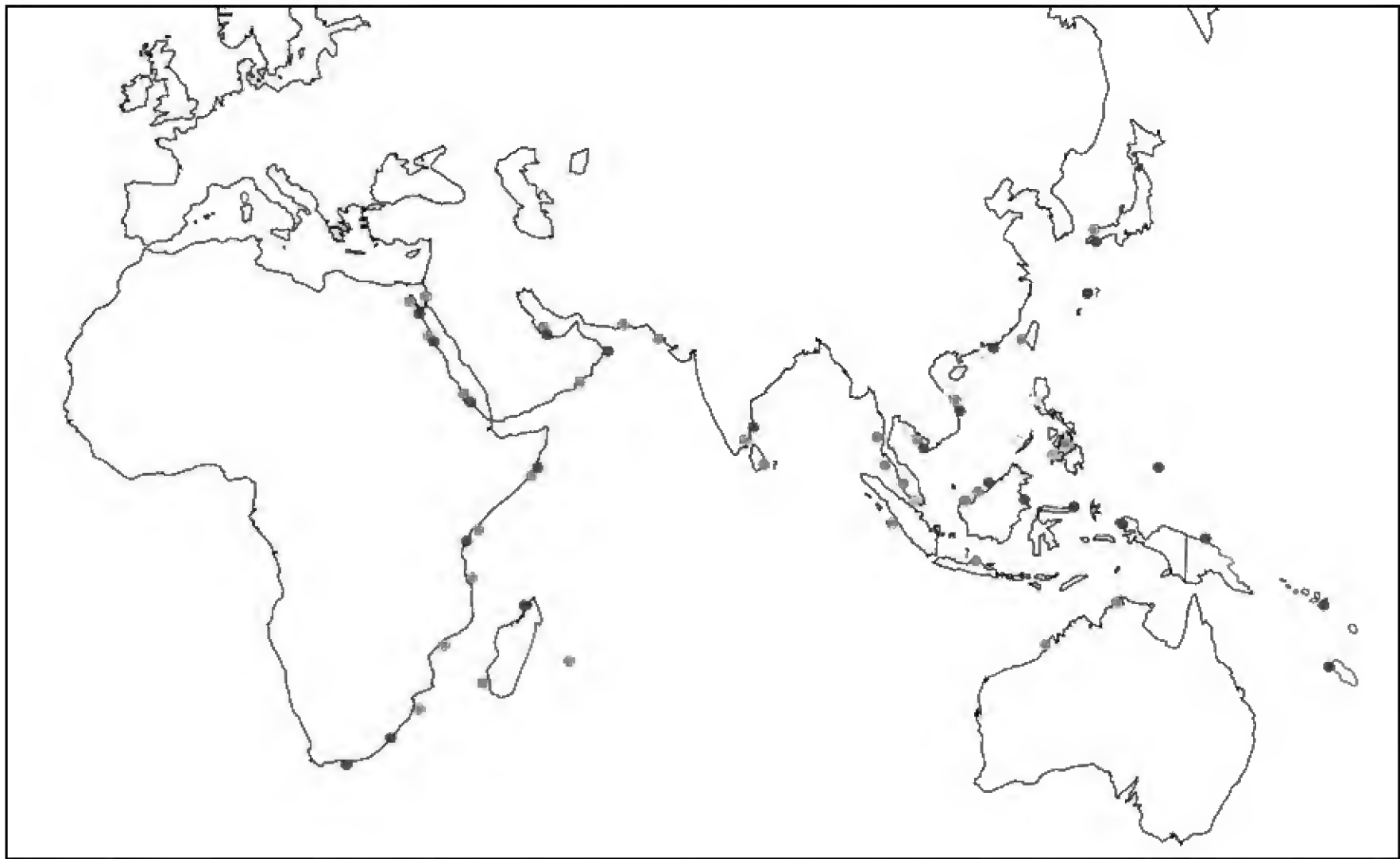
Figure 17. Distribution of extant main "*Echinodiscus*" morphotype, *Sculpsitechinus* and *Paraamphiope* species. From Mooi (2014) the GBIF portal; Ashley (personal communication, Dec. 2013); Hattenberger (personal communication, Dec. 2013), Mooi (1989). Other data by cited authors. Yellow dots: *Sculpsitechinus auritus* group. Blue dots: *S. tenuissimus*. Orange dots: *Echinodiscus andamanensis* n. sp. Grey dots: *E. truncatus*. White dots: "*Echinodiscus*" cf. *tenuissimus*. Green dots: *E. bisperforatus* group. Light blue dots: *Paraamphiope raimondii* n. sp.

Proto-Mediterranean sea and then to the Middle East; the other one towards the Western Pacific basins to the north of the Eurasian continent.

Figure 18 shows the phylogenetic hypothesis emerged from this research.

TAXONOMIC CONCLUSIONS

In the samples we analyzed there are clear internal structural differences between *Echinodiscus* and *Amphiope*. Important differences can also be observed at the specific level, especially in the morphology of the central hollow floor.

To understand some of undetermined features in the fossil individuals, the use of living species specimens for the comparison allowed us to solve several problems that were unsolved for a long time.

Despite the great variability in shape and lunules/notches size shown by some groups of astriclypeids, the shape of the lunule remains an important data for the specific distinction. We have seen that other characters are also useful to specific and generic distinction; particularly, we should consider the platings of the two test faces, and the differences in the internal structure, where possible. The comparison of pedicellaria and spines, not always considered in this work, need further studies, particularly in the living populations and can help us in the determination of the variety and/or species, also by molecular examen.

The detection of the test plating allowed comparisons based on reliable data; the use of appropriate indicators in the statistical comparison, as operated by Stara & Borghi (2014) can provide, moreover, a further diagnostic tool.

Among the astriclypeids examined in this work, the specimens of the Chattian-Aquitanian from Cuccuru Tuvullao have the highest number of plates in the inter. 5, the backward position of the periproct (with respect to the post-basicoronal plates on inter. 5) and also the highest number of couples of plates surrounded the lunules. These characters and the massive and strong structure make them apparently the most archaic of all the taxa included in this com-

parison group. It follows that this *Amphiope* does not descend from *E. formosus*, but from an older common ancestor. This is also true for *E. pedemontanus*, "*Amphiope*" *duffi* and *E. desori*, which can not be the ancestor of the said *Amphiope*.

Also the comparison of the internal structures between *Amphiope* and *Sculpsitechinus* makes it clear that these two groups are not as similar as they seem, but their common origin moves further back in time.

As a result of these observations, it is clear that all forms of *Amphiope* bearing round or transverse lunules, today grouped under the specific name of *A. bioculata*, as proposed by Philippe (1998) need to be revised, since their distinctive characters have not yet been published up to now or have been underestimated. It is obvious, moreover, that among the species of *Amphiope* of Sardinia and those of the group of "*Echinodiscus*" there is no direct connection.

In this group of comparison, the knowledge of the arrangement, number and size of the post-basicoronal plates that characterizes the oral face of the inter. 5 and the aboral one, shows a different subdivision of the genera and a species distinction previously unrecognized. Referring to the data obtained with our present work, we can say that the petalodium size has a diagnostic importance at generic level: it is small in echinoids of the new group *Sculpsitechinus* (30–47%) and wider in *Amphiope* (45–60%). In any case, this characteristic must be always used together with others, since in some groups, such as the *E. bisperforatus*, it is very variable.

Given the different morphologies and morphometric diversity observed between the samples of "*E. bisperforatus*" group here examined (Plate 4 Figs. 1-8), we believe that there is also the basis for looking for the presence of different species, but this will be the subject of future research. Jansen & Mooi (2011) propose the examen of the pedicellaria of living echinoids to differentiate species. In paleontology, unfortunately, this possibility is almost always precluded, since the soft parts or the minute parts hardly preserve in the sediment. However, careful observation of the skeletal parts, such as test, internal structures, Aristotle's lantern, can partially allow the distinction between genera and also between species, acting as a support of the soft parts study.

Despite the lack of available data, we can already say that the genus of French "*Amphiope*" bearing axial lunules, such as *A. agassizi* and *A. boulei*, and of the East regions, such as *E. placenta*, from Miocene of India, are not real *Amphiope* or *Echinodiscus*; these species should be re-studied and assigned to different genera. However, the morphological and morphometric comparison of Miocene astriclypeids as "*Amphiope boulei*", "*Amphiope*" sp. from Libya, "*E. bisperforatus*" from Papua New Guinea, with those that characterize the new genus *Sculpsitechinus*, allow us to assume that the first ones may be the ancestors of the latter one and all are detached from *Amphiope* and *Echinodiscus*.

Even the series from ?Eocene to Miocene, *Echinodiscus formosus-E. yeliuensis* and living *E. bisperforatus* could be consistent. In fact, all these echinoids share some distinctive characters such as the angle ß and the distance between lunules and petals tips, which places themselves in a close phylogenetic relationship, and detaches them from both *Amphiope*, *Sculpsitechinus* and *Paraamphiope*. Strictly speaking, even the *Echinodiscus formosus*, *E. jeliuensis* and *E. bisperforatus* series should be moved in a separate genus, but also in this case it is needed to restudy the specimens of Taiwan and deeply study also the different forms of living "*E. bisperforatus*".

It is also evident the diversity of *E. transiens* from all other supposed congeners, in particular by the dimension of the sole visible lunule, and by the petalodium size, that would fit it between the real *Amphiope*. Even in these cases, however, nothing certain can be defined, until we know the oral face plating of the specimens in object.

With regards to the astriclypeids present in the Middle East Miocene, despite the different works published (among others, see Kier, 1972), the illustrations and platings published are insufficient to determine with any certainty the belonging to a genus rather than another. From bibliographical data we believe it could be *Echinodiscus* or *Paraamphiope*, but only a new study will clarify the real systematic position of these echinoids. We add only that, according to a specimen present in NHMUK London, *Amphiope* was also present in the Miocene of Mosul (Iraq) and in the Gulf of Aqaba (Arabian peninsula).

Finally, although we have observed that the condition of open petals is quite common in the astriclypeids and perhaps also in other scutellids of neighboring families, this important character, mentioned by Airaghi (1899;1901), joins *Echinodiscus pedemontanus* to "*Amphiope*" *duffi* and *E. desori*, and allows us to reconfirm the existing link between their regions.
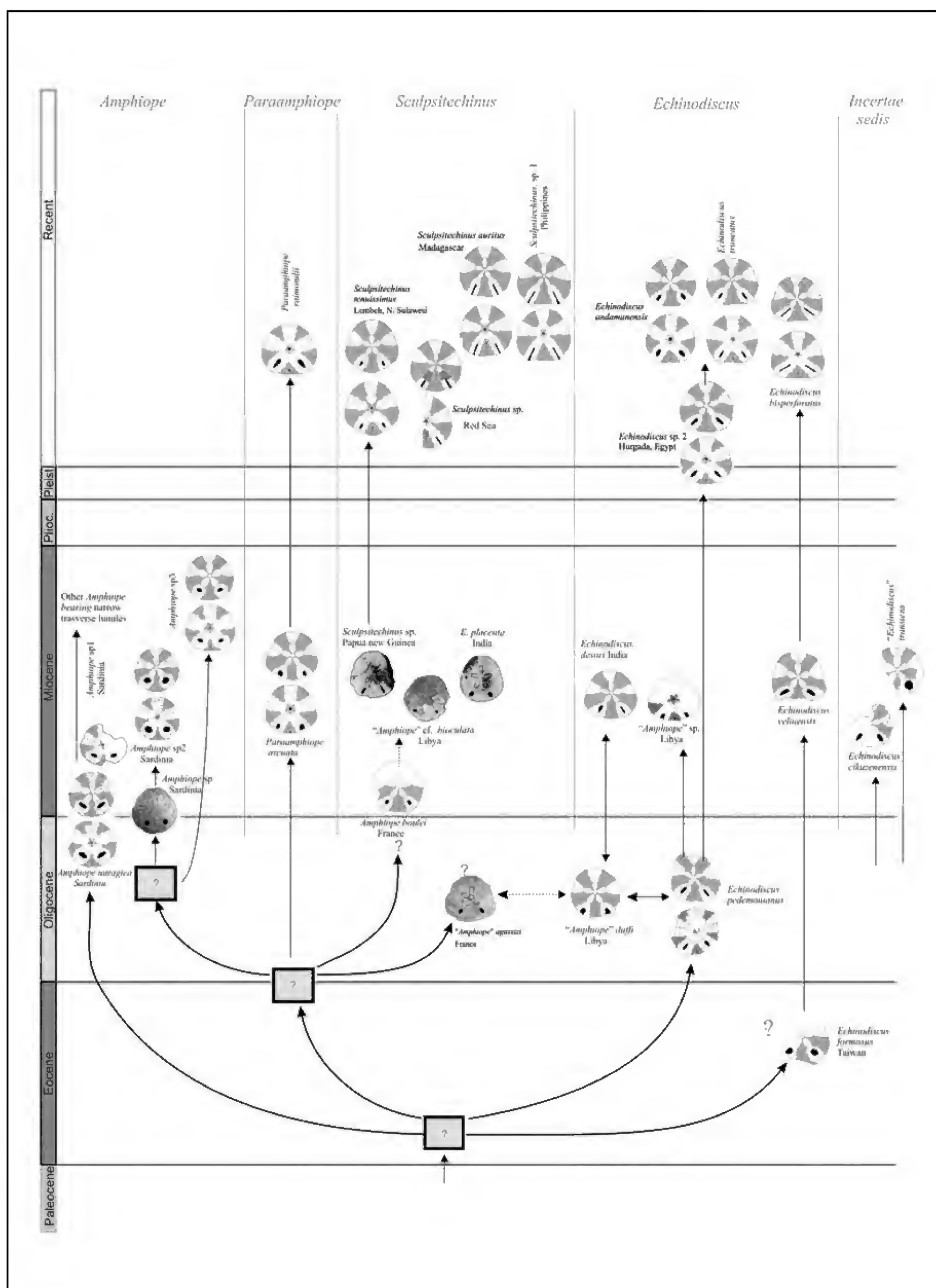
Figure 18. Hypothesis of phylogenetic relationships between *Amphiope*, *Echinodiscus*, *Paraamphiope* and *Sculpsitechinus* genera.

All three of these echinoids have some petals which are open or partially open, an uncommon (or ignored) character in echinoids of this family. Indeed, we observed in *E. bisperforatus* that even one or more petals are open or tend to be open. Based on these conclusions, in figure 18 is proposed a new phylogenetic hypothesis, waiting appropriate cladistic new studies on the genera and species of this family.

In conclusion, according to the results highlighted, four clusters emerge at the generic level of species hitherto treated and a new distribution of living species studied as in figure 17.

1. *Amphiope*, including: *A. nuragica*; *Amphiope* sp. 1; *Amphiope* sp. 2 from Bancali; *Amphiope* sp. 3 from Channay-sur-Lathan and all other species from Sardinia treated by Stara & Borghi (2014)

2. *Paraamphiope*, including "*Amphiope*" *arcuata* from Libya and "*Echinodiscus tenuissimus*" from Indonesia, here renamed *Paraamphiope arcuata* and *P. raimondii* n. sp.

3. *Echinodiscus*, including: *E. bisperforatus*; *E. andamanensis* n. sp. and *E. truncatus*; *E. formosus*, *E. cikuzenensis*, *E. jeliuensis*, *E. desori*; finally, *E. pedemontanus* and *Echinodiscus* sp. 1 from Italy and *Echinodiscus* sp.2 from Red Sea.

4. *Sculpsitechinus*, including all the "*Echinodiscus* cf. *auritus*"; "*Echinodiscus tenuissimus*" of New Caledonia, Micronesia and some "*E. tenuissimus*" from Indonesia; "*Echinodiscus bisperforatus*" of Papua New Guinea, which would be a new species. All renamed here as follows: *Sculpsitechinus auritus* from Mangili; *S. tenuissismus*, *Sculpsitechinus* sp. 1 and *Sculpsitechinus* sp. 2.

All other nominal species of "*Amphiope*" and "*Echinodiscus*" discussed herein and not included in these four groups will have to be reviewed, given the few characteristics known at the present.

Finally, a clear zonation of living *Sculpsitechinus* and *Echinodiscus* in the Indo-Pacific Seas is highlighted, as a prelude to further investigations about the old bibliographic citations on the presence of "*Echinodiscus* cf. *tenuissimus*" in the Oceania and in the Andaman Sea (see Fig. 17).

In order to facilitate the understanding of the main characteristics that differentiate the species and genera treated here, we have summarized the main differences in Tables 13 and 14.

Speci-mens	Apx	PL	WA	ß
IVM82	4.5	39	34	55
IVM83	5	38	31	53
IVM84	4.5	38	32	57
IVM85	4.5	40	29	49
IVM86	4.5	40	33	58
IVM87	4.5	38	30	56
IVM88	4.5	36	32	56
IVM89	4.5	39	32	50
IVM90	4.5	38	32	54
IVM91	6	40	34	59
IVM92	5.5	41	32	54
IVM93	5.5	41	32	56
IVM94	5.5	38	31	57
IVM95	5	39	33	62
IVM96	5	39	33	54
IVM97	5.5	43	33	57
IVM98	5.5	41	32	53
IVM99	5.5	38	29	58
IVM100	4	39	35	56
IVM101	5	41	31	53
IVM102	5.5	41	32	53
IVM103	5	43	31	56
IVM104	5	41	33	55
IVM105	6	42	33	57
IVM106	5.5	38	31	59
IVM107	5	37	31	48
IVM108	4.5	40	37	
IVM109	5	40	31	54
IVM110	4.5	43	32	53
IVM111	4.5	38	34	65
IVM112	6	47	37	55
mean	5.6	39.8	32.3	55.4
Range	4 - 6	36-47	29-37	48 - 62

Table 11. Apx, PL, WA andß data in the sample of *Sculpsitechinus auritus*. ß in degree, other data in % TL.

Table 12 (right). Simplified morphometric data of *Echinodiscus*, *Paraamphiope* and *Sculpsitechinus* samples from different localities; TL in mm, ß in degree, other measures in % TL.

Specimen	TL	TH	L1	L2	S1	L4	L11	WA	PL	ß
Echinodiscus andamanensis PMBC 26346	81	9,1	11.3	5.6	0,49	55	5.1	-	49	85
Echinodiscus andamanensis PMBC 2642	66	9,5	17.6	6.8	0,38	53	4.2	-	51	83
Echinodiscus andamanensis PMBC 2643	66	10,1	12.1	5.2	0,43	52	7.6	-	51	68
Echinodiscus andamanensis PMBC 2644	66	10,1	15.5	4.9	0,31	52	9.6	-	53	73
Echinodiscus andamanensis PMBC 2830	54,6	9,1	14.9	5.2	0.35	53	4.1	-	46	75
Echinodiscus andamanensis PMBC 2643.1	50	.	13	5.1	0.39	51	7.2	-	52	71
E. andamanensis ZMUC-ECH-1001	37	-	15	6.7	0.44	53	6.5	38	45.5	71
E. andamanensis NL	-	-	13.3	4.1	0.30	50	6.8	36	47	78
Mean E. andamanensis		9,58	14.3	5.4	0.44	52	6.6	37	49	75.5
MAC.PL 1850	31	11	18	6	0.33	56	5.5	37	44	81
MAC.IVM 206.	59	13.5	20	6.6	0.33	51	7	36	42	80
E. truncatus. Singapore S137a	60	-	14.6	4.2	0.28	57	9.5	37	49	68
E. truncatus. Singapore S137	51		15.3	3.9	0.25	57	10	37	51.5	65
E. truncatus. Singapore S1			19.6	4.2	0.21	57	10.8	37		71
E. truncatus. Singapore S2			17.6	4.2	0.21		10.3			64
E. truncatus. Singapore S3			17.6	3.4	0.19	57	11.5		50	67
Mean E. truncatus			16.9	3.98	0.22	57	10.4	37	50	67
Sculpsitechinus tenuissimus	TL	TH	L1	L2	S1	L4	L11	WA	PL	ß
N. Cal. in Dollfus & Roman	121	-	12.5	4	0.32	54	11	31	30	65
NHMUK.59.7.1.14	112	9	10	4	0,4	54	13	31	38	70
NHMUK.1981.112.25	120	9	12.5	3.5	0,28	55	10	31	45	67
ANU 60549	70	—	14	4	0.28	—	..	32	46	61
MAC.IVM 207	50	10	13	4	0.30	56	11	34	35	66
Lembeh 1	62	8	13	5	0,38	—	14	33	34	74
Lembeh 2	60	-	13	5	0,30	56	16.5	35	35	68
N. Cal. 1 (Hattemb. coll)		-	16	4,5	0.28	56	17	33	37	61
Mean Sculpsitechinus tenuissimus		9	11,7	4,2	0,28	55	13,2	32,5	37,5	66,5

Table 13 (down). Comparison between different old and new astriclypeid genera: contact between interambulacral plate 2b and the adjacent ambulacral plates. A= amphiplacous; M=meridoplacous. ß in degree, other data in % TL.

Genus	PL	Main characters of inter. 5				L11	other
		WA	A	M	ß		
Astriclypeus	47	39		x	75	19	5 ambulacral lunules; floor of the central hollow reinforced by massive thickening; highly branched food grooves
Amphiope	45-61	29-46	x		----	4-13	Transverse or rounded posterior lunules; floor of the central hollow reinforced by massive thickening; simply food grooves
Paraamphiope	42-46	31-38	x		75-?100	3.5-12	Axial posterior lunules; floor of the central hollow reinforced by ribs; highly branched posteriorly food grooves
Echinodiscus "tenuissimus group"	40-50	35-38		x	70-81	5.5-8	Axial posterior lunules; floor of the central hollow reinforced by ribs; simply food grooves; sometime branched posteriorly food grooves
Echinodiscus "bisperforatus group"	38-50	45-54		x	100-117	3.5-12	Axial posterior lunules; floor of the central hollow reinforced by ribs; sometime branched posteriorly food grooves
Sculpsitechinus	30-47	30-33		x	48-70	11-24	Axial posterior lunules; floor of the central hollow reinforced by network of ribs or trabeculae; highly branched food grooves
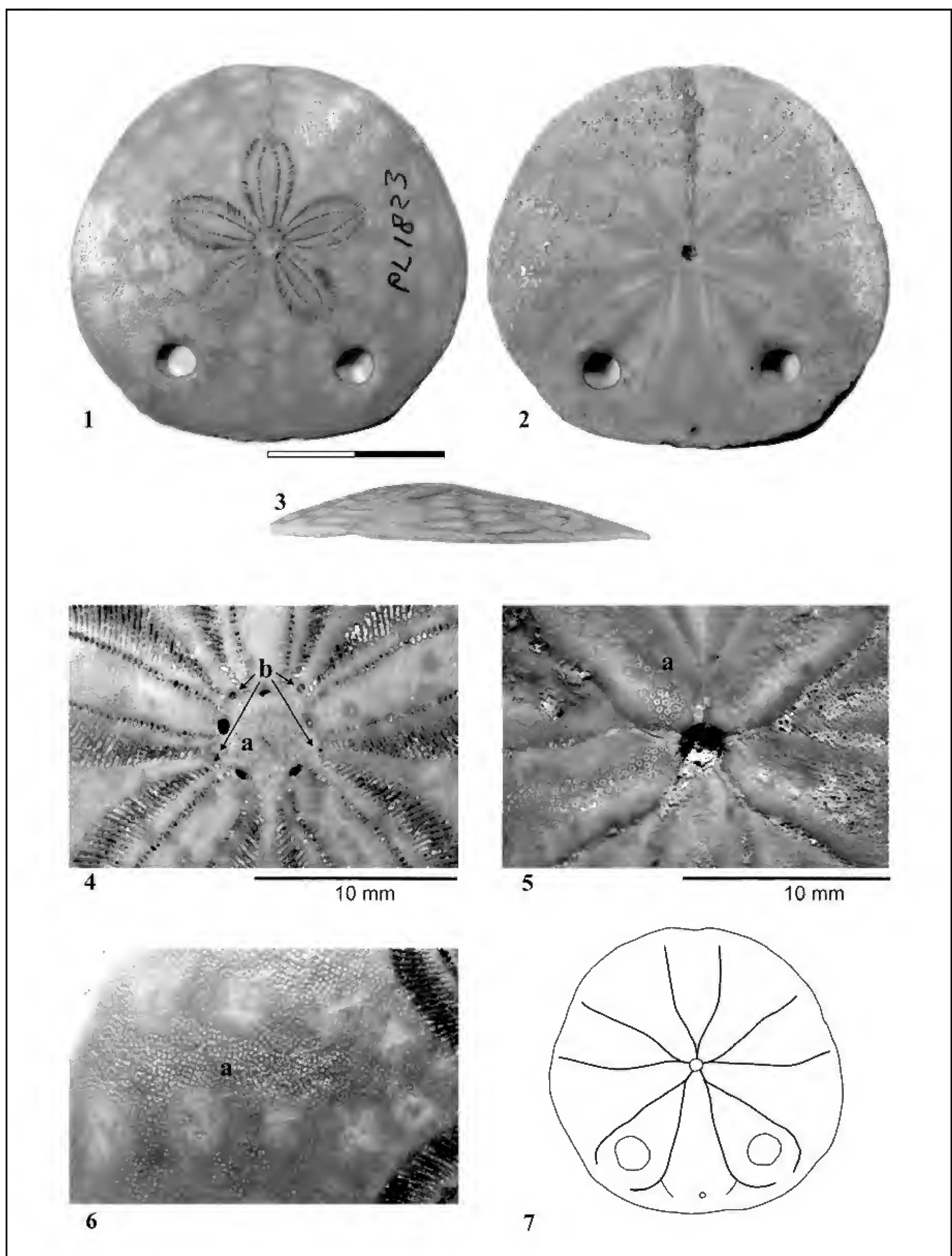
Plate 1. *Amphiope* sp. 3 from Channay-sur-Lathan, France (late Serravallian-early Tortonian): external features. Figs. 1–3. Aboral, adoral and antero (to the left)-posterior (to the right) lateral view of MAC.PL1823; Fig. 4. Apical disk with (a) madreporite (b) genital pores; the other pores at the tips of the petals are ocular pores; Fig. 5. Stoma, basicoronals circlet with tuberculation and food grooves; Fig. 6. Aboral view with (a) undifferentiated tuberculation; Fig. 7. Pattern of very simple food grooves.
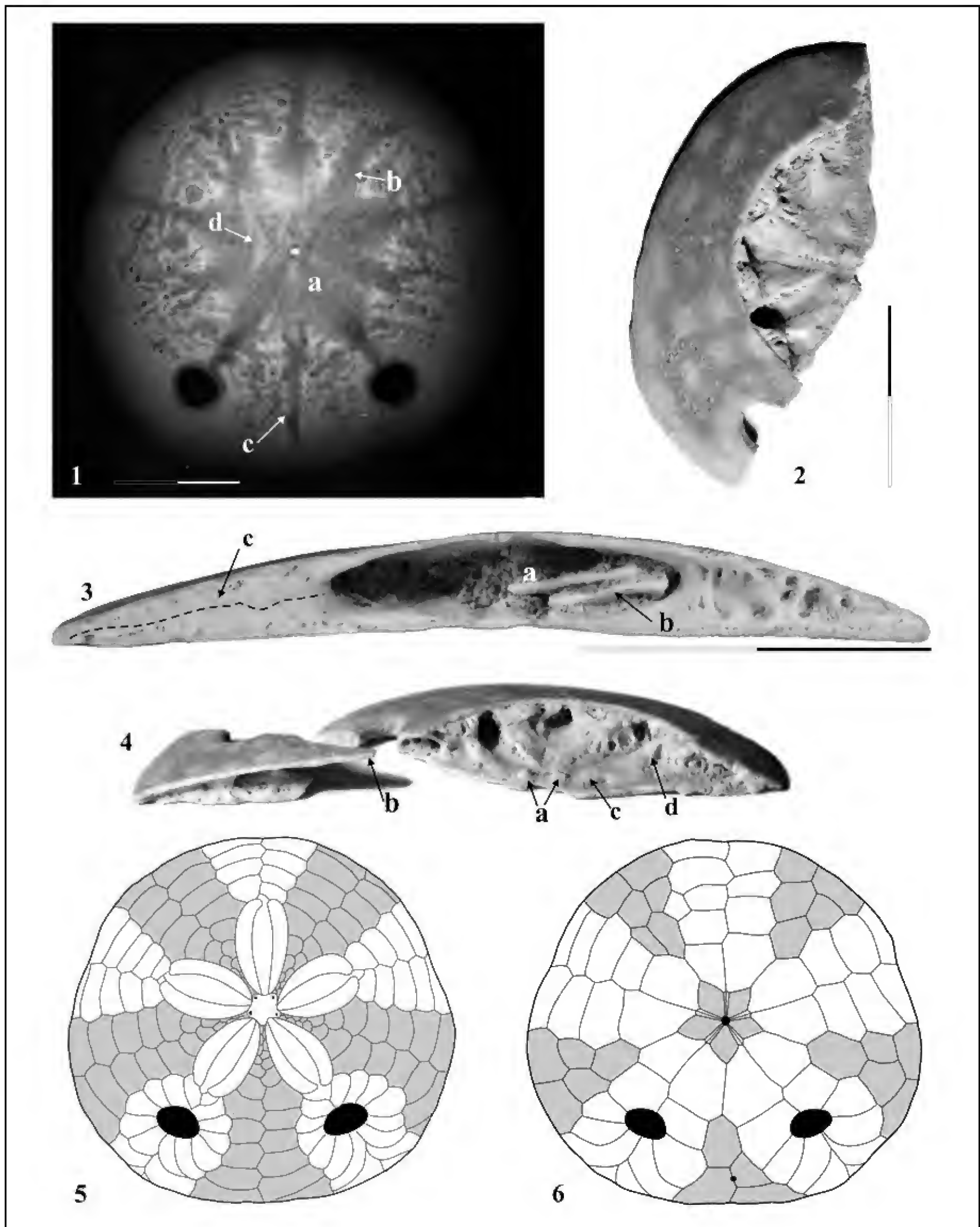
Plate 2. *Amphiope* sp. 3 from Channay-sur-Lathan, France (late Serravallian-early Tortonian): internal features and plating. Fig. 1. radiography of MAC.PL1668; a: central hollow; b: caecum cavity; c: terminal intestine cavity; d: small disarticulated Aristotle's lantern. Fig. 2. Test fragment showing the internal structures of the central hollow. Fig. 3. Cross antero (to the right)-posterior (to the left) section of the test; a: central hollow; b: wings of the Aristotle's lantern c: middle conjunction plan of the reinforcement structures. Fig. 4. Antero-posterior cross-section of the echinid; a: lantern supports; b: section of ceiling; c: massive floor reinforcement; d: pillars and buttresses of the peripheral reinforcement system. Fig. 5. Plating of aboral face of MAC.PL1668. Fig. 6. Plating of adoral face of MAC.PL1668.
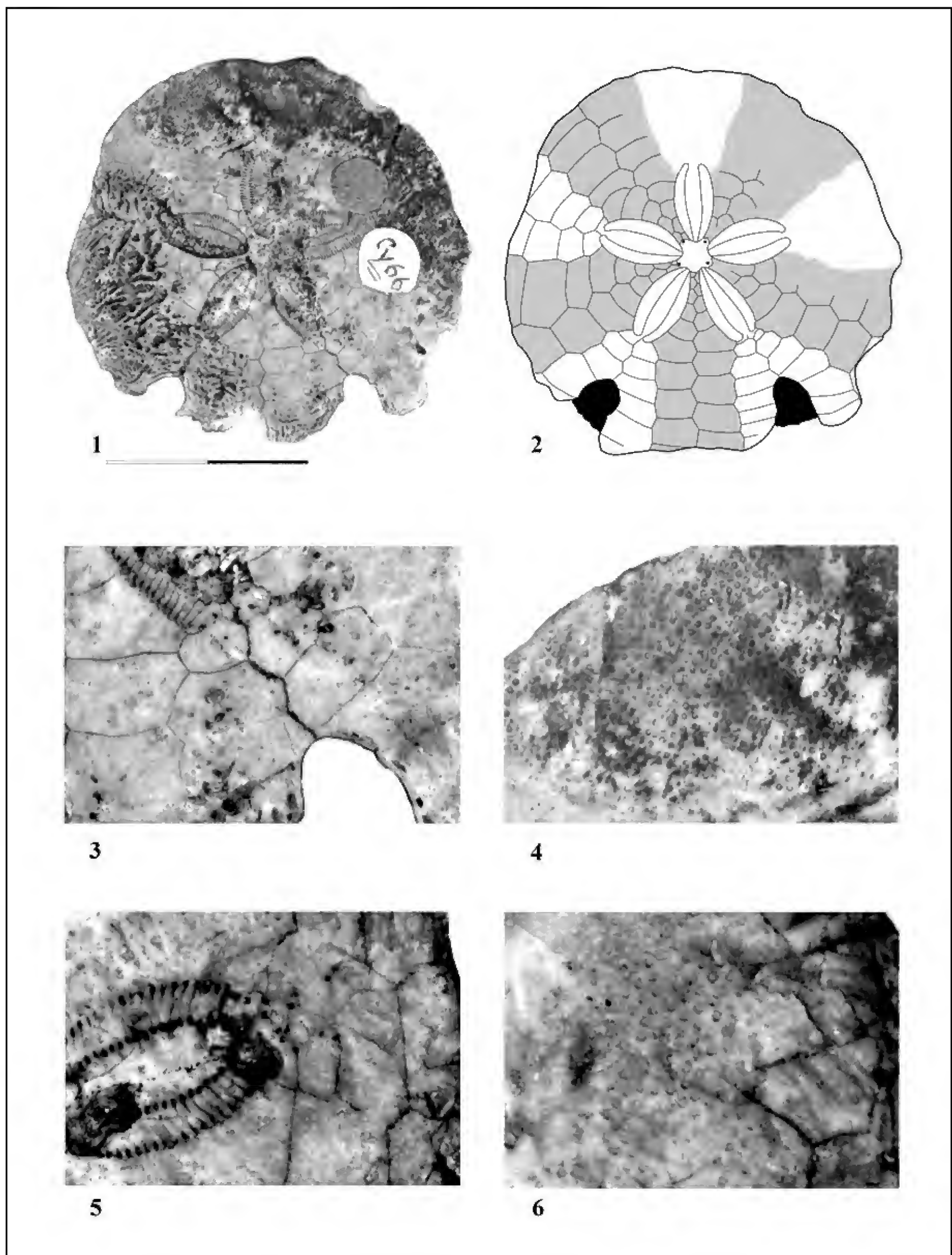
Plate 3. "*Amphiope*" *duffi* from Sidi Rof Diasiasia, Cyrenaica, Libya (early Oligocene). Figs. 1, 2. Aboral view of NHMUK: CY66/E11350 and corresponding aboral plating. Figs. 3, 4. Open posterior right petal and aboral tuberculation of NHMUK.CY66. Figs. 5, 6. Ambulacrum II with open tip and aboral tuberculation on NHMUK.CY264. In particular, from Figures 3 and 5 it is noted that in the tip of the petals no plate is occluded.
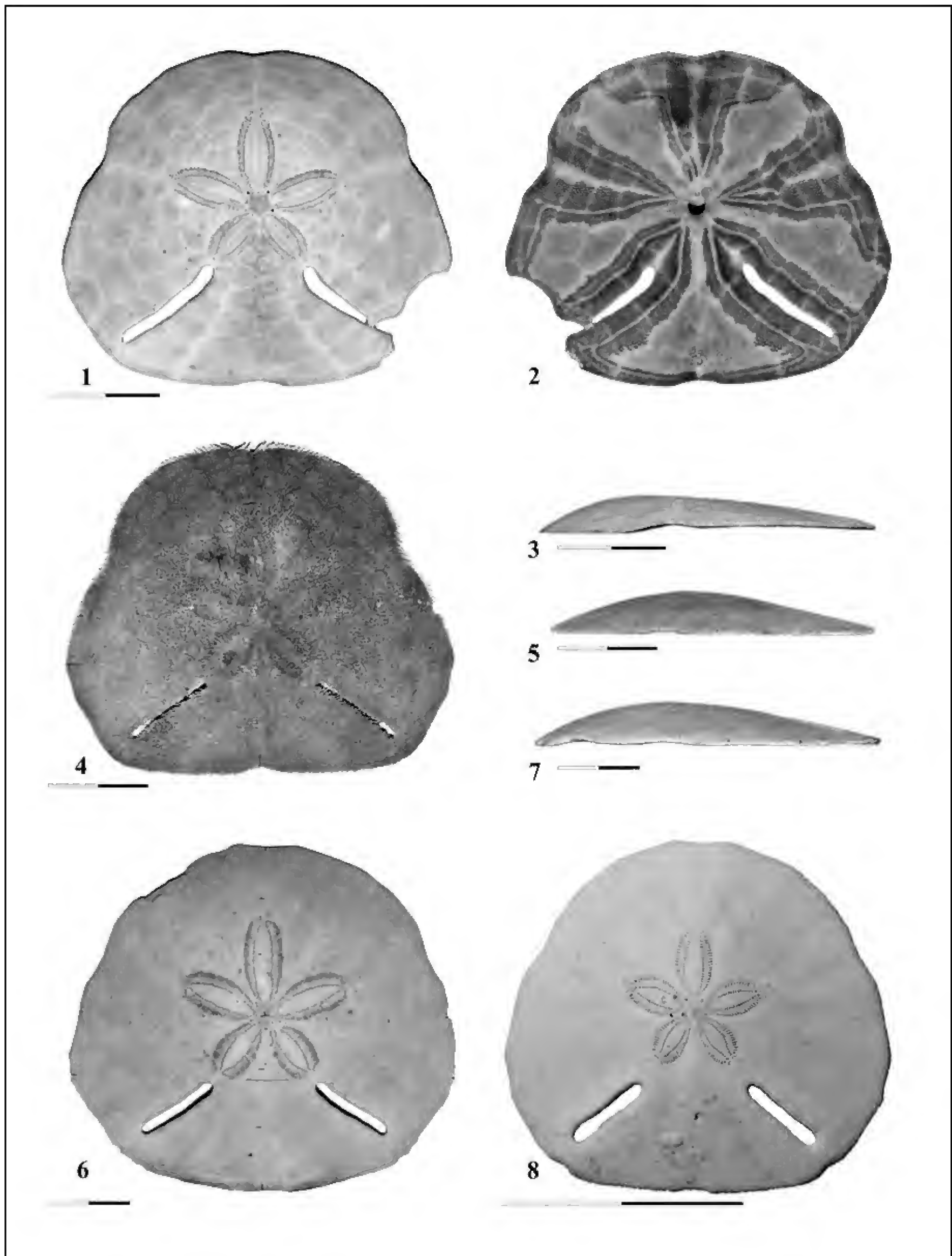
Plate 4. *Echinodiscus bisperforatus* from different localities (Recent). Figs. 1–3. Aboral, adoral and antero (to the left)-posterior (to the right) lateral view of NHMUK.2013.7 from South Africa. Figs. 4, 5. Aboral and antero (to the left)-posterior (to the right) lateral view of NHMUK.2013.3, from Eritrea. Figs. 6, 7. Aboral and antero (to the left)-posterior (to the right) lateral view of NHMUK.1957.5.21.3, from Tanzania. Fig. 8. Aboral face of juvenile IVM.206 from north Madagascar.
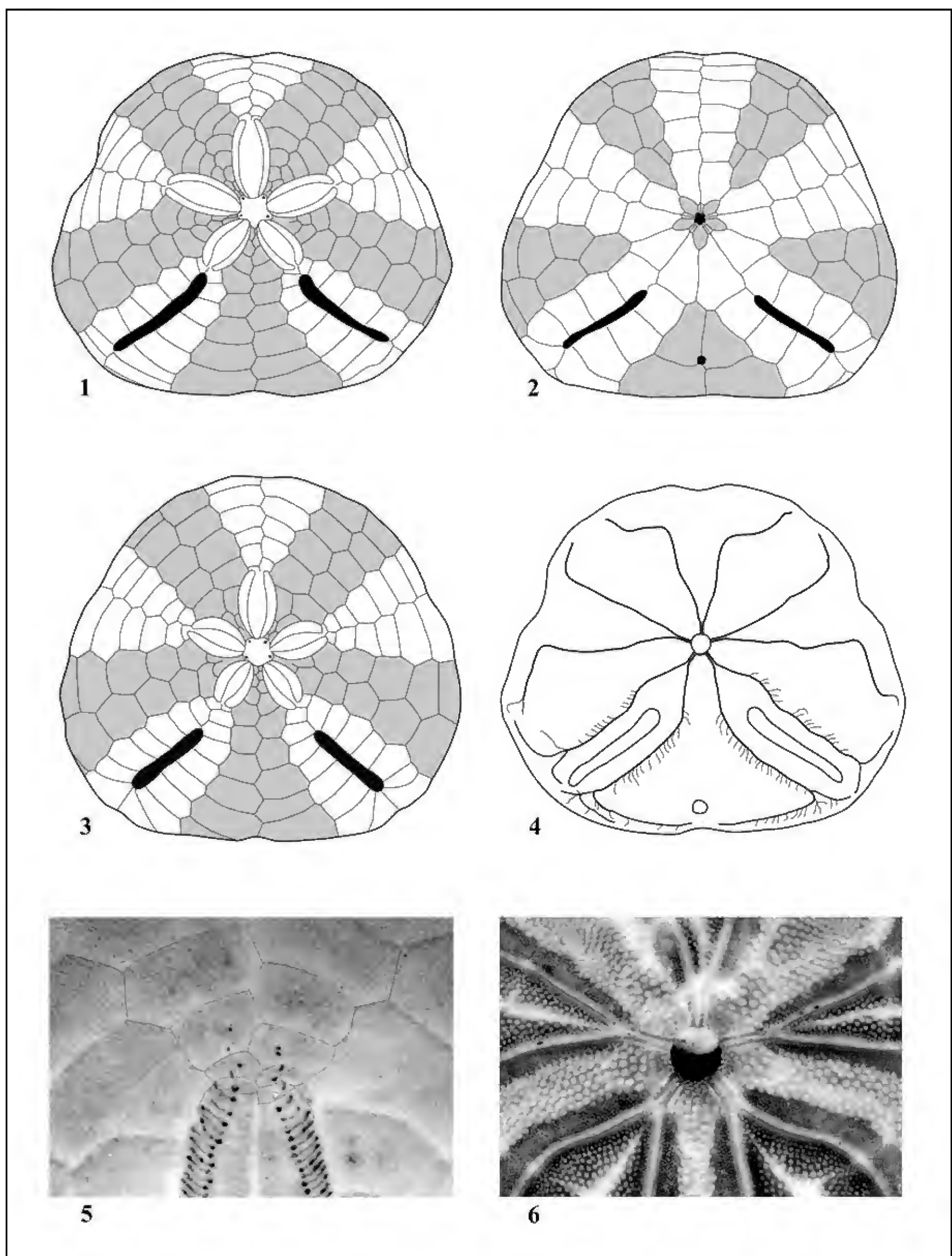
Plate 5. *Echinodiscus bisperforatus*, platings and peculiarities in specimens from different localities (Recent). Figs. 1, 2. Plating of aboral and adoral face in two specimen from South Africa. Fig. 3. Plating of aboral face in MAC.IVM.206, juvenile from Madagascar. Fig. 4. Scheme of food grooves in a specimen from South Africa. Fig. 5. Open anterior odd petal in NHMUK.2013.7 from South Africa. Fig. 6. Peri-oral tuberculation in specimen NHMUK.2013.7 from South Africa.
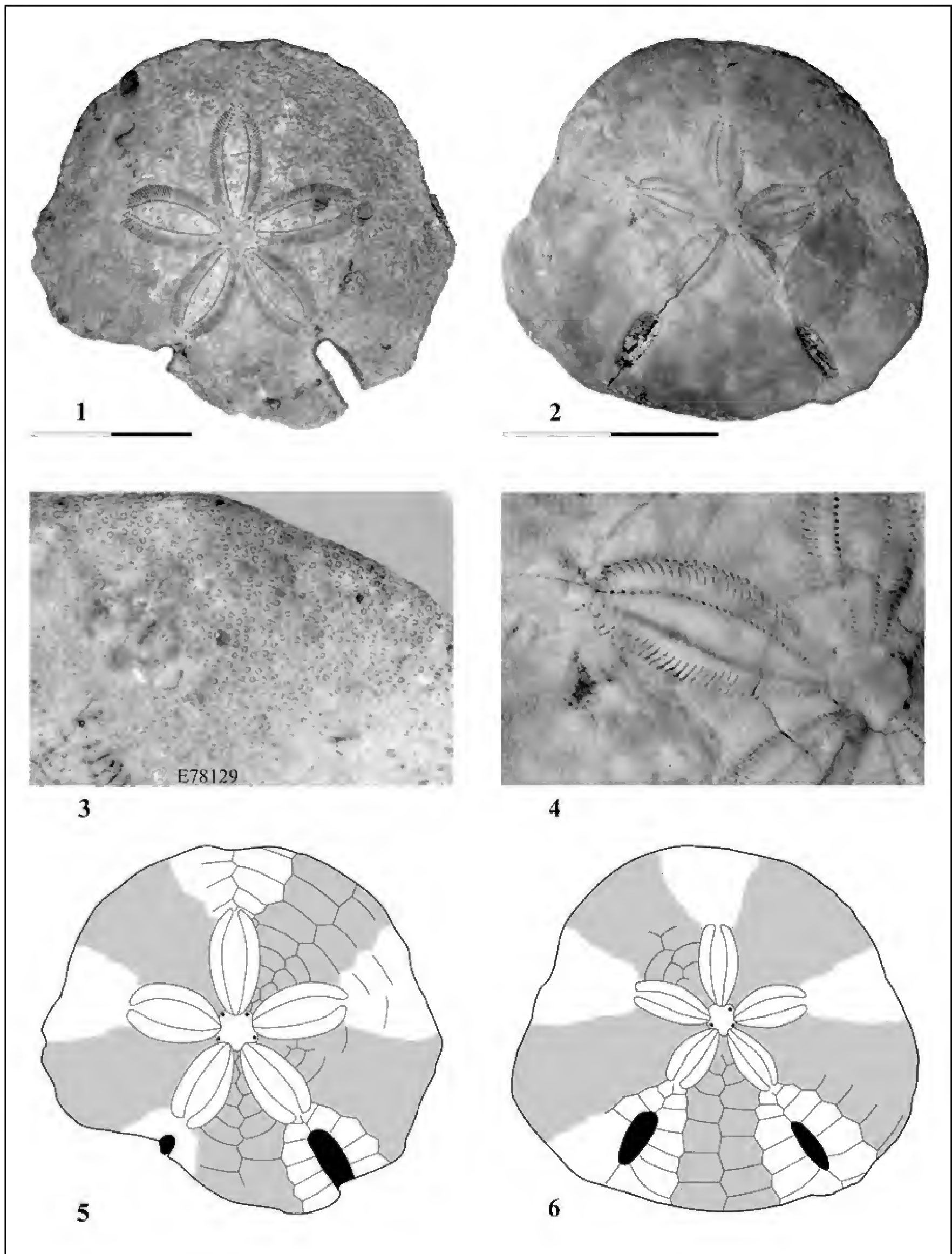
Plate 6. *Echinodiscus desori* from India (Miocene). Fig. 1. Aboral face of NHMUK.E78128a. Fig. 2. Aboral face of NHMUK.E78129. Fig. 3. Aboral tuberculation, NHMUK.E78129. Fig. 4. Ambulacrum IV with open tip, NHMUK .E78129. Fig. 5. Plating of aboral face of NHMUK.E78128a. Fig. 6. Plating of aboral face of NHMUK.E78129. Is noticeable that these samples have in common with those of Cyrenaica some petals open.

Plate 16
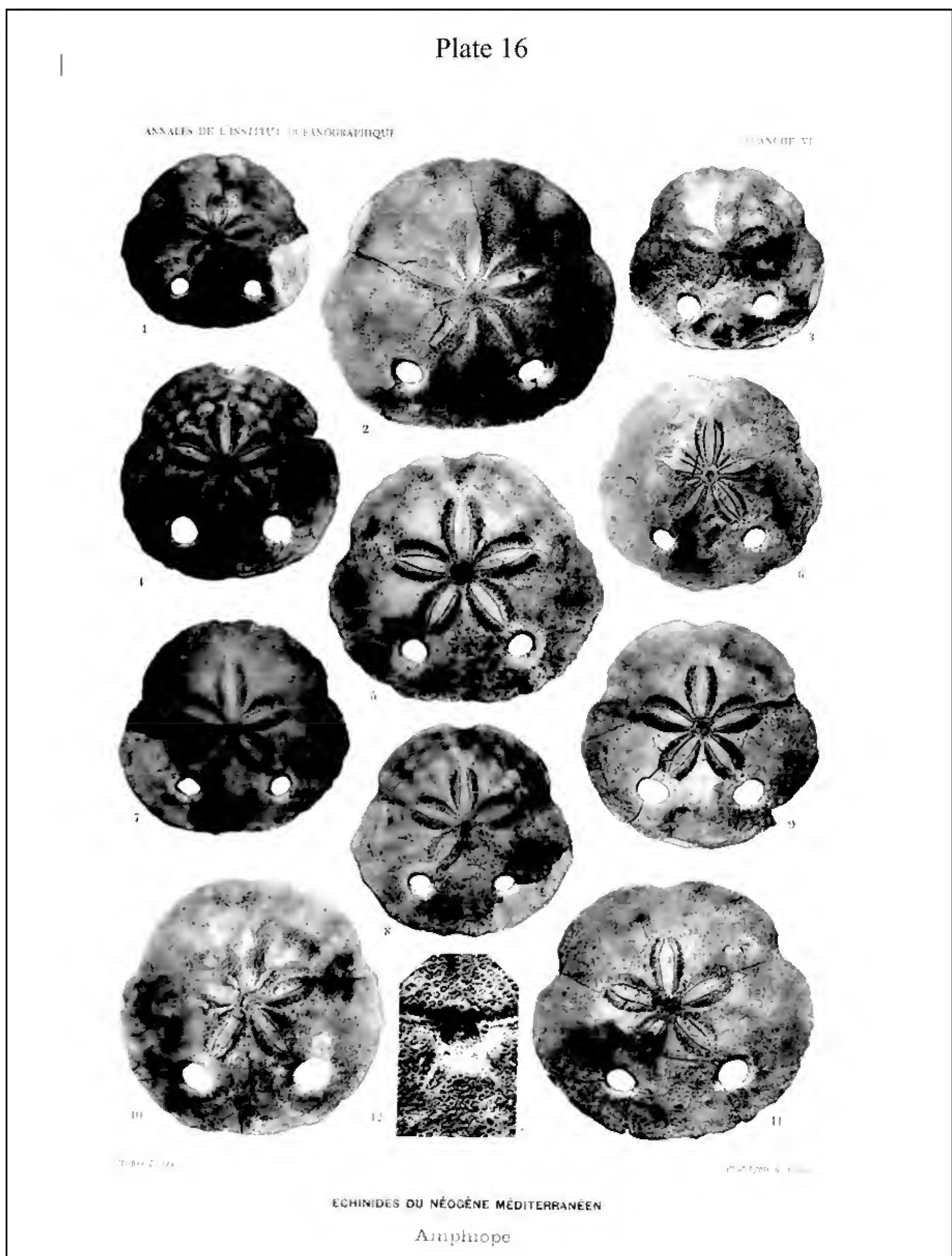
Plate 7. In this fine example of morphological variability of a small portion of *Amphiope* population, Cottreau (1914) shows visually what the morphometric data has confirmed. But inadvertently he also highlights that none of these forms can match with those of other species, such as, for example, *A. nuragica*. However, looking closely at the lunules, one can also see the normal deformations and growth differences between the two lunules of the same specimen.
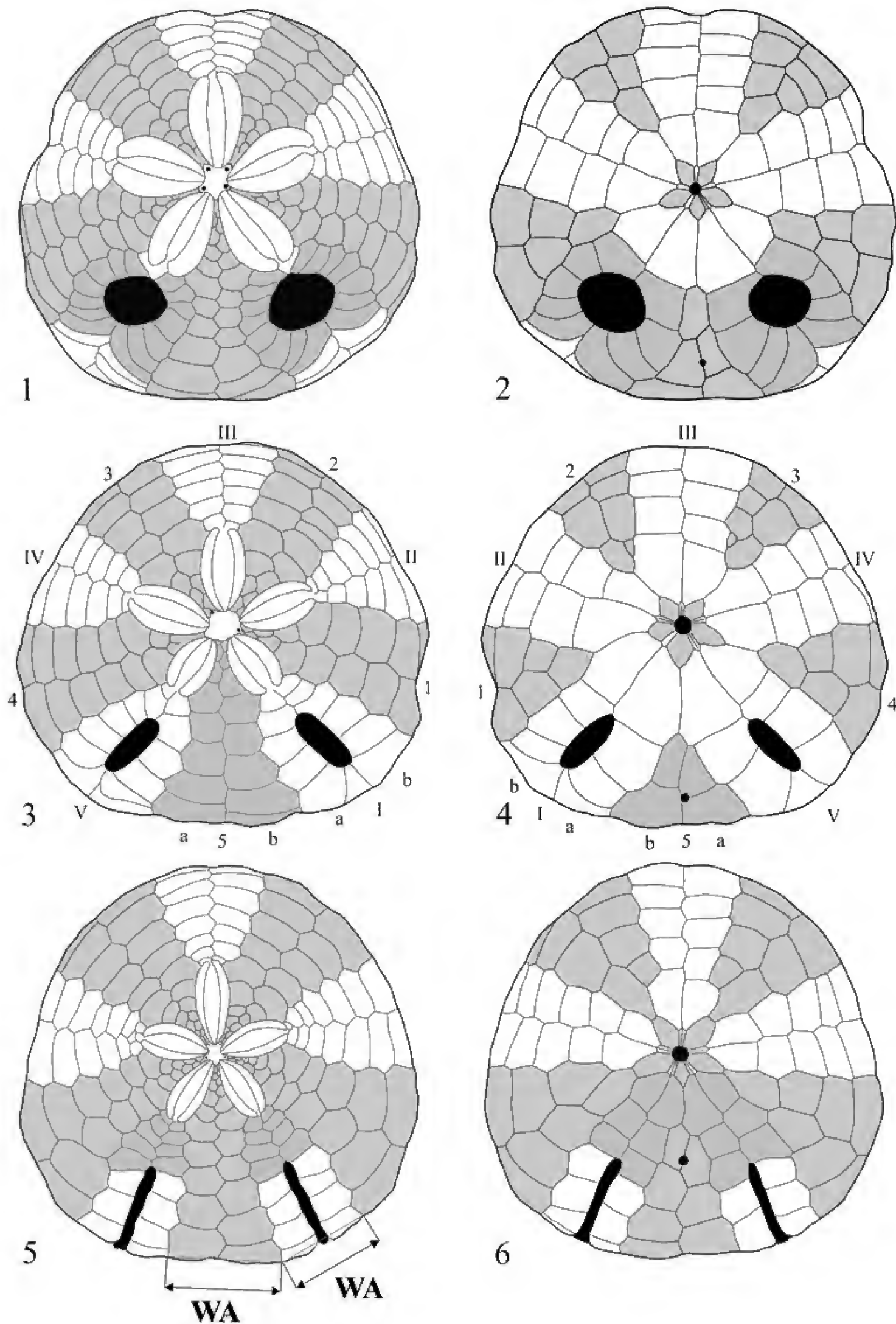
Plate 8. Examined features colored in reddish; interambulacra shaded gray. Figs. 1, 2. *Amphiope montezemoloi*, arrangement of plates surrounding lunules in oral and aboral face. Figs. 3, 4. *Echinodiscus* sp. 2, plate arrangement of interambulacum 5 on oral and aboral faces; numbering according to Loven's System. Fig. 5. *Sculpsitechinus auritus*, plates between notches and petal tips; measure of ambulacral and interambulacral areas at ambitus. Fig. 6. *S. auritus*, plates between basicoronals and notches.
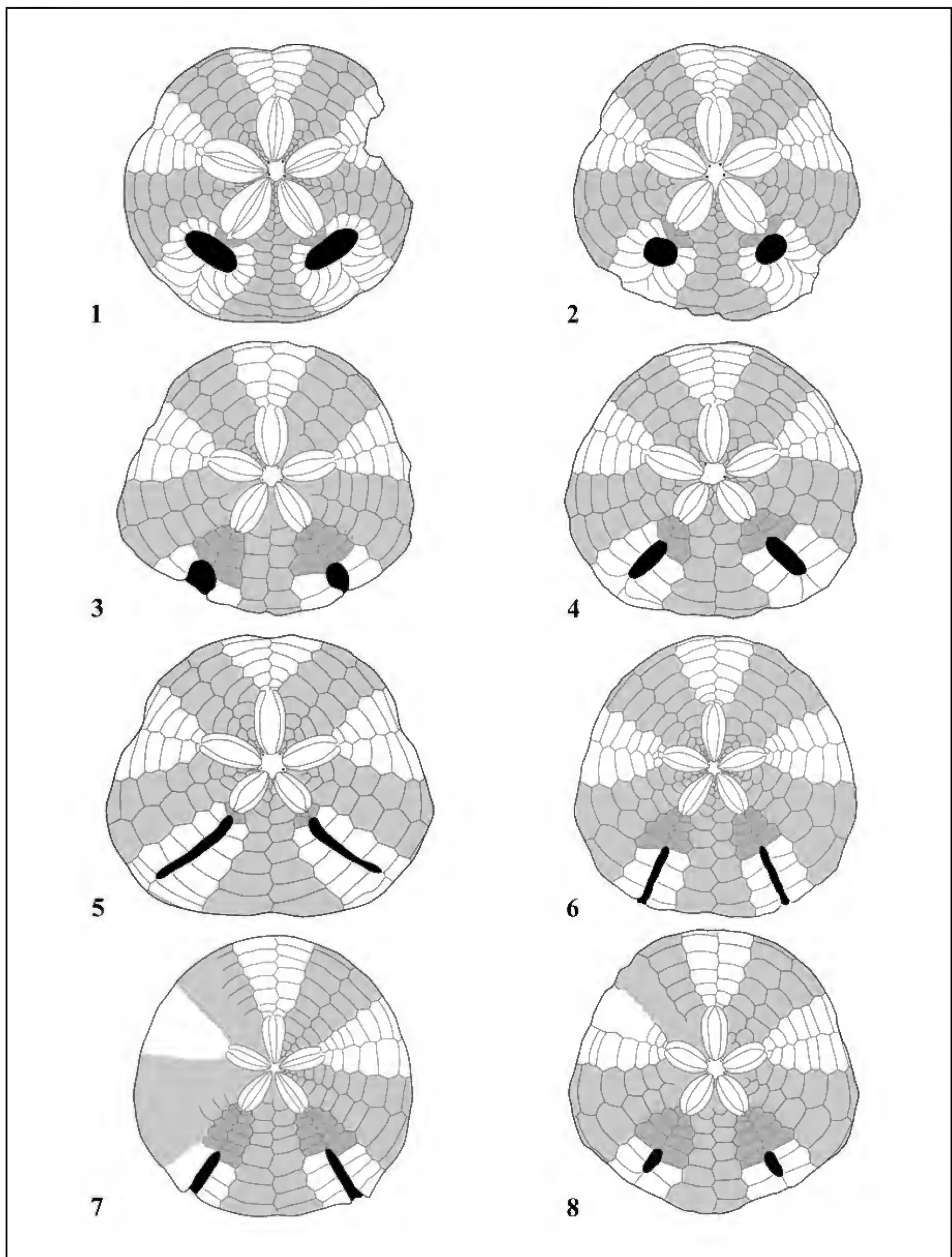
Plate 9. Comparison of number of plate couples between lunules and petal tips on aboral faces-examined features colored in reddish, interambulacral columns shaded gray. Fig. 1. *Amphiope nuragica*. Fig. 2. *Amphiope* sp. 2 from Bancali, Sardinia. Fig. 3. *Paraamphiope arcuata*. Fig. 4. *Echinodiscus* sp. 2. Fig. 5. *Echinodiscus bisperforatus*. Fig. 6. *Sculpsitechinus auritus*. Fig. 7. *Sculpsitechinus* sp. Fig. 8. *Sculpsitechinus tenuissimus*.
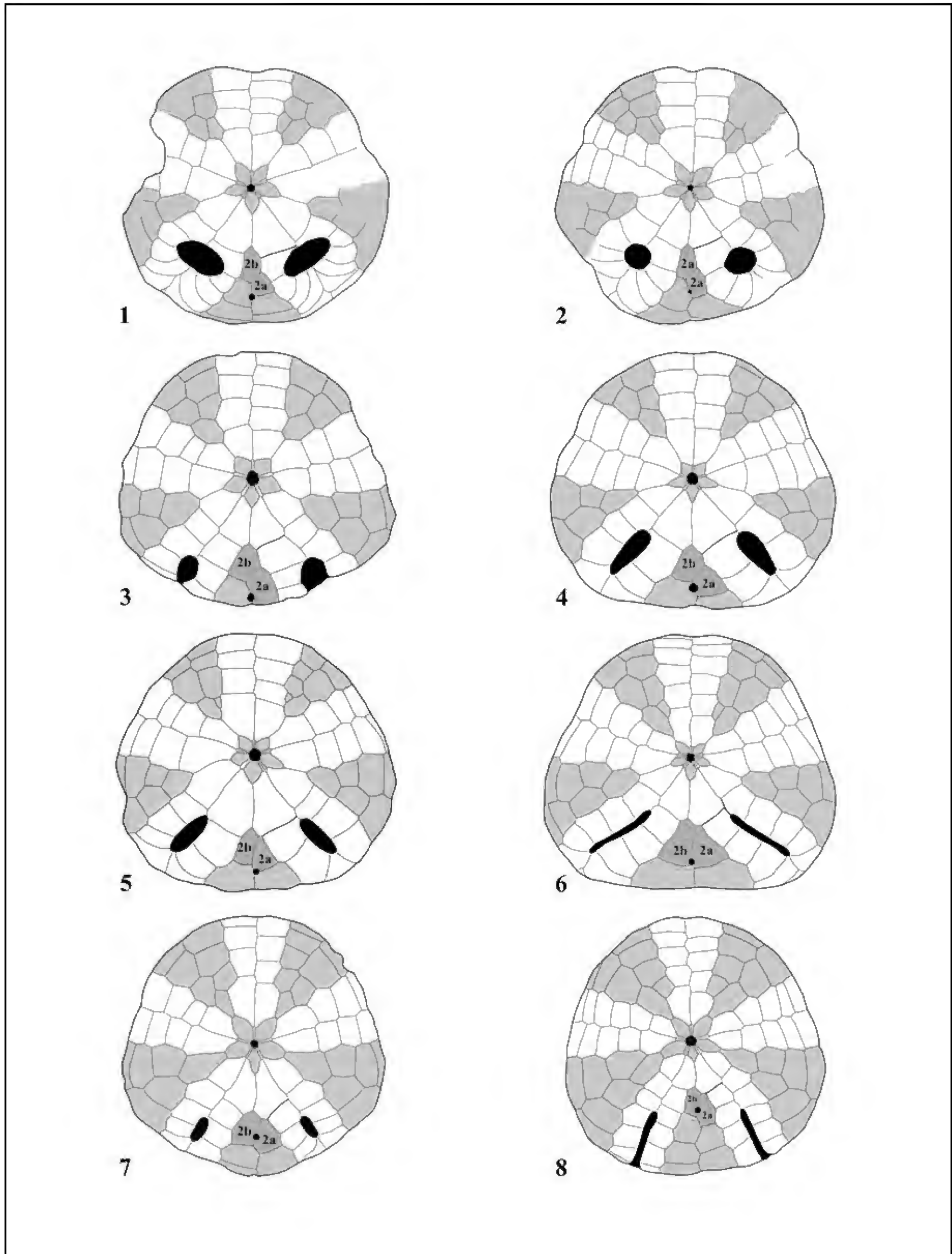
Plate 10. Comparison of number, shape and disposition of plates on oral interambulacrum 5 - examined features colored in reddish, other interambulacral columns shaded gray. Fig. 1. *Amphiope nuragica*. Fig. 2. *Amphiope* sp. 2 from Bancali, Sardinia. Fig. 3. *Paraamphiope arcuata*. Fig. 4. *Paraamphiope raimondii*. Fig. 5. *Echinodiscus* sp. 2. Fig. 6. *Echinodiscus bisperforatus*. Fig. 7. *Sculpsitechinus tenuissimus*. Fig. 8. *Sculpsitechinus auritus*.
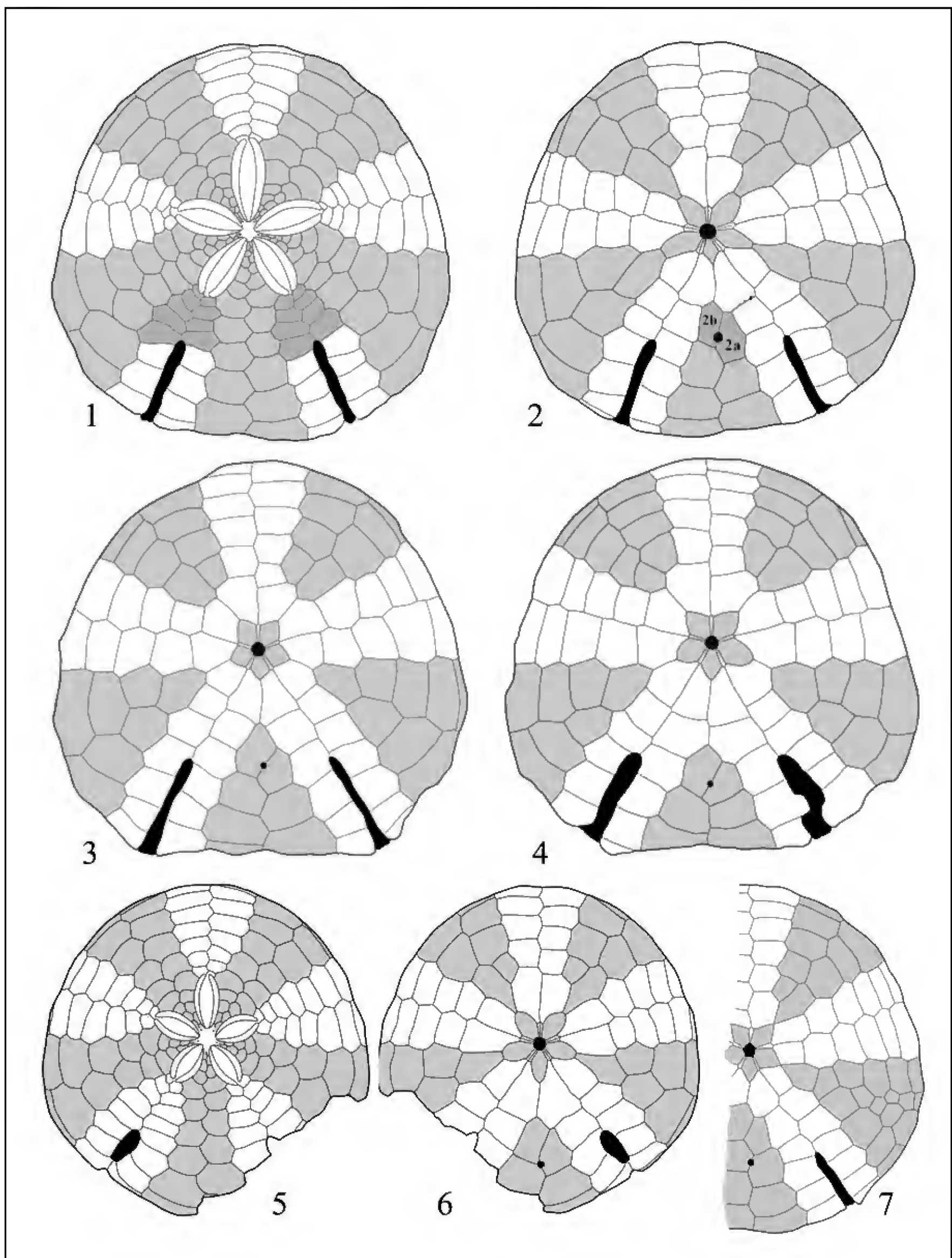
Plate 11. Plating features comparison in *Sculpsitechinus* species, interambulacral columns shaded gray. Fig. 1, 2. *Sculpsitechinus auritus*. Fig. 3, 4. *Sculpsitechinus* sp. 1 from the Philippines. Fig. 5, 6. *Sculpsitechinus tenuissimus* from Lembeh, Indonesia. Fig. 7. *Sculpsitechinus* sp. (in Agassiz, 1841). We can observe some common features: large number of plates between lunules/notches and the petal tips; high number of plates in the oral interambulacrum 5.
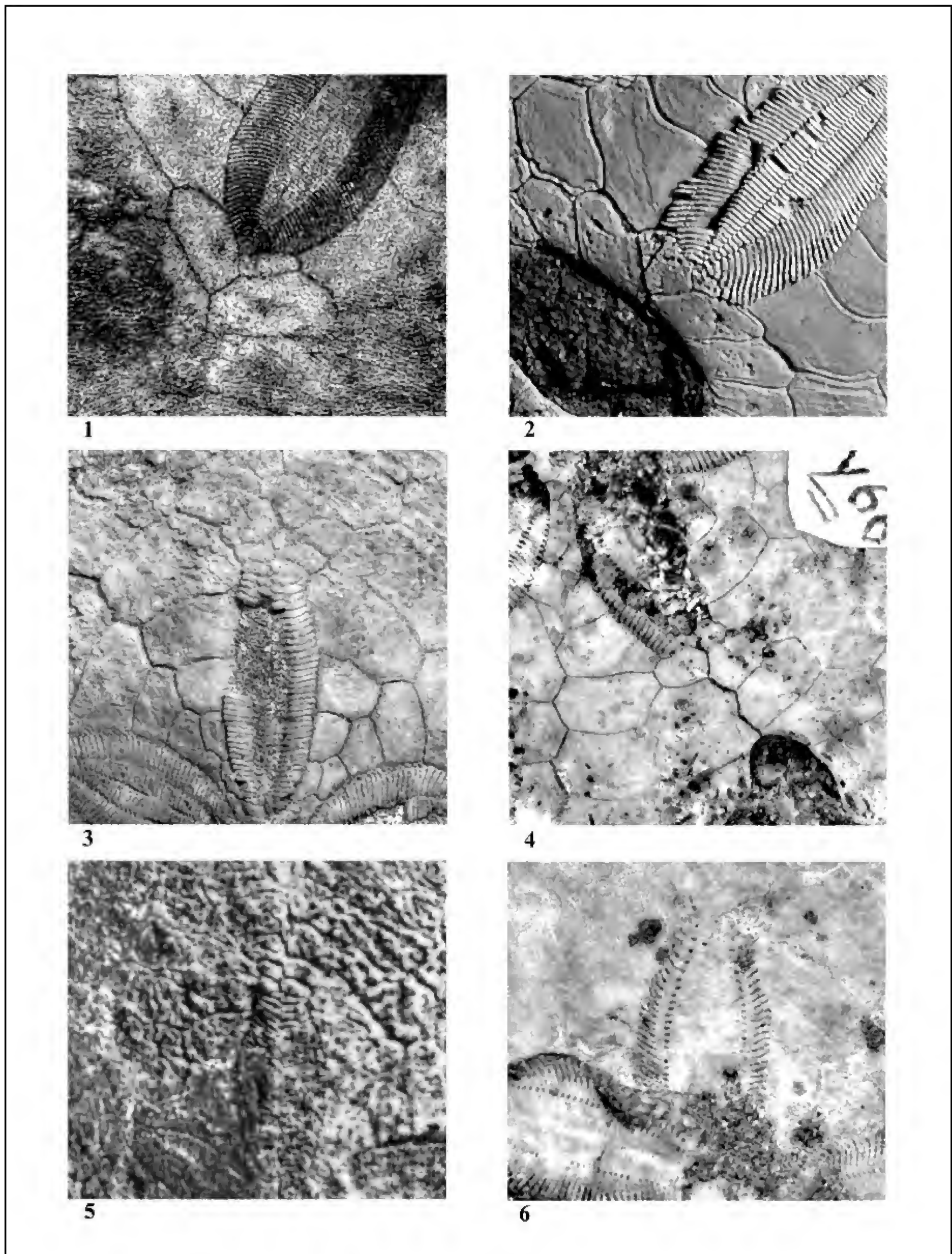
Plate 12. Petals open and petals closed in living and fossils species. Figs. 1. *Sculpsistechinus auritus* from Mangili: closed petal tip with occluded plates. Figs. 2. *Amphiope nuragica*: closed petal tip with occluded plates. Figs. 3, 5, 6. *Echinodiscus pedemontanus*: anterior odd petal open;3 and 5 with gradual tip plate downsizing. Fig. 4. "*Echinodiscus*" *duffi*: posterior right petal tip open.
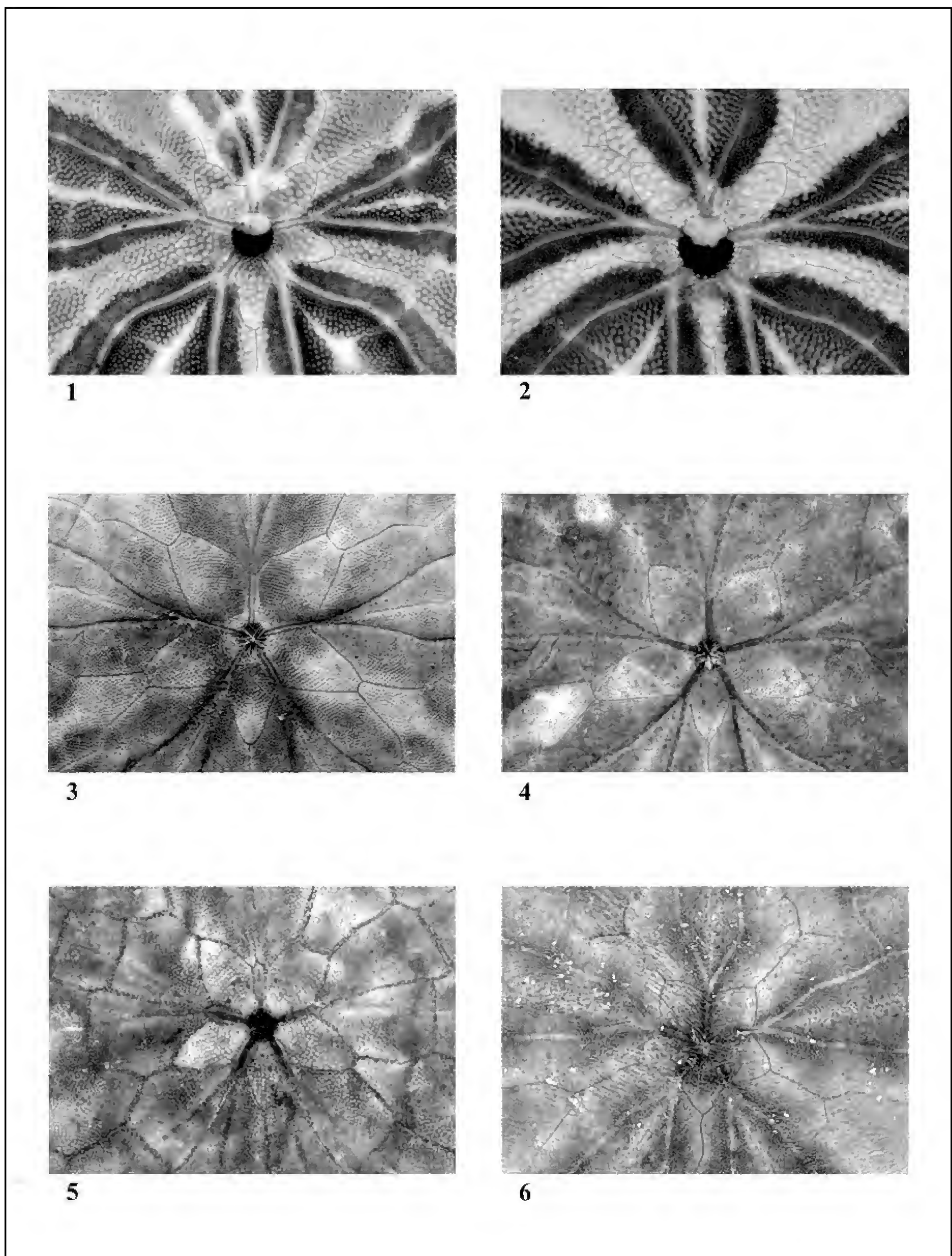
Plate 13. Random contact between basicoronal and relate postbasicoronal interambulacral plates in *Echinodiscus* and *Sculpsitechinus*. Figs. 1, 2. *E. bisperforatus* (South Africa). 1: interambulacra 2, 3 in contact; 1, 4, 5 disjoint; 2: disjoint. Figs. 3–5. *S. auritus* (Mangili): MAC.IVM110, interambulacra 1, 2, 3, 4 in contact; 5 disjoint; MAC.IVM115 4 in contact; MAC.IVM84, interambulacra 2, 3 in contact; 3, 4, 5 disjoint. Fig. 6. *S.* sp. 1 (Philippines) MAC.IVM218: interambulacra all disjoint.
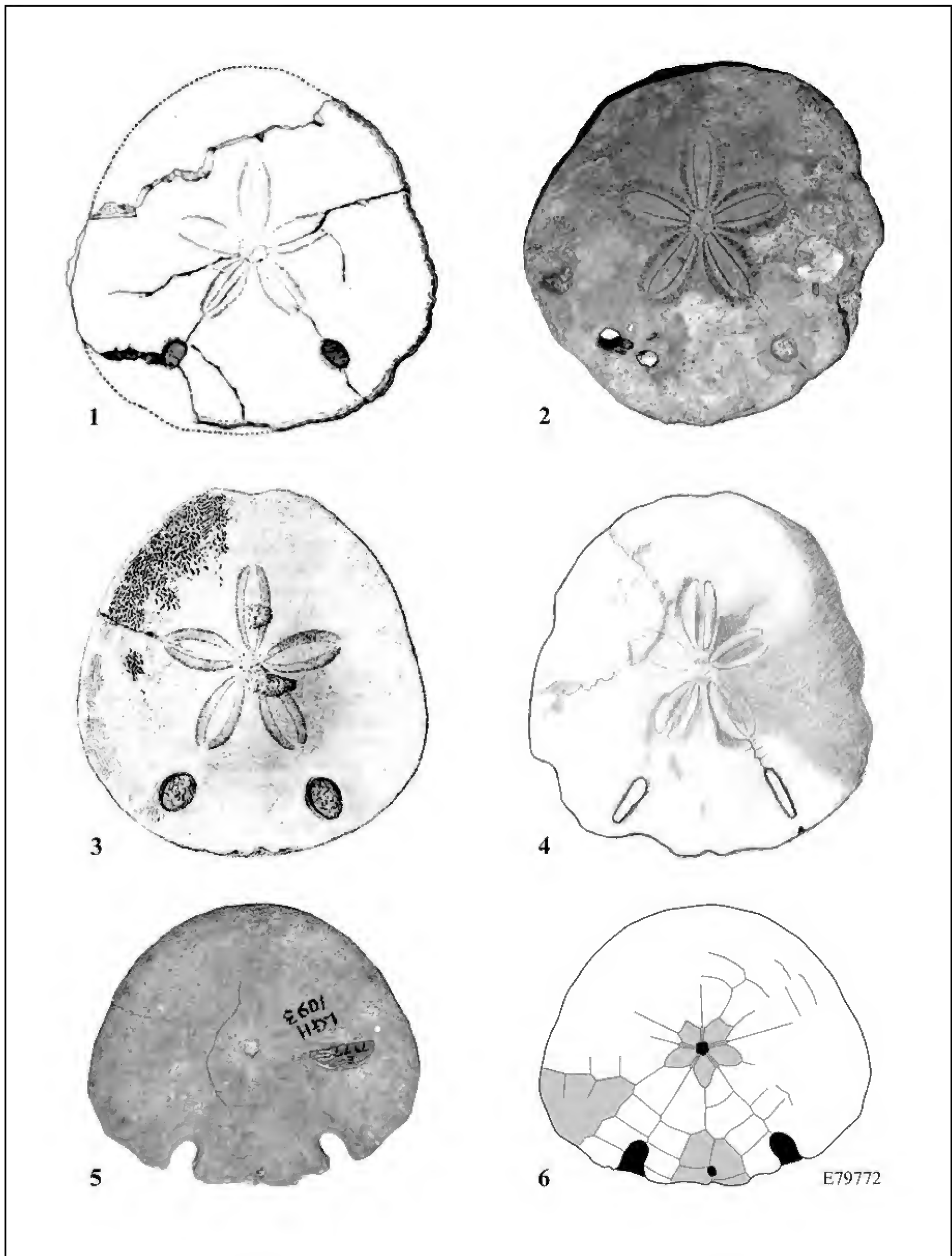
Plate 14. Other astriclypeids morphotypes. Fig. 1. Aboral face of "*Amphiope*" *boulei* (pl. 5, fig. 9). Fig. 2. Aboral face of "*A.* cf. *bioculata*" from Libya, specimen NHMUKE5788. Fig. 3. Aboral face of "*Echinodiscus*" *placenta* (Duncan & Sladen, 1883: pl. 52 fig. 1). Fig. 4. Aboral face of *Sculpsitechinus* sp. 2, in Lindley, 2001 (Fig. 7d). Fig. 5. Adoral face of "*Amphiope*" sp. from Libya, Miocene, NHMUK E79772. Fig. 6. Adoral plating pattern of "*Amphiope*" sp. from Libya, Miocene, NHMUK E79772.

Species	Pc posit.	Lunules or notches		Space (L3) and plates between lunules and (a) petals or (b) basicoronals			other
		L1	L2	L3	a	b	
Paramphiope arcuata	2a/3b	11,5	7	15	4-4	3-4	Lunules ellipsoidal in shape
Paramphiope raimondii	2a/3b	13	4	7	1-2	2-3	Lunules slit-like
Echinodiscus pedemontanus	2a/3b/3a 3b/3a	15	6	8	3-4	2	Petals open
Echinodiscus andamanensis	2b/2a	14	5,4	10	2-4	2	Petals closed; ß = 75,5°; WA = 38% TL
Echinodiscus truncates	2b/2a/3b	16	4	10			Petals closed; mean ß =67°; WA = 38% TL
Echinodiscus bisperforatus	2b/2a 2b/2a/3b	30-34	3	3	1-2	2	Virtually closed petals; long slit-like lunules mean ß = 100°; WA = 48-50 %TL
Sculpsitechinus sp. (in L.Agassiz)	3b/3a	19	3	19	6-6	3-4	Posterior notches
Sculpsitechinus tulearensis	2a/2b	24	2	13	4-5	3-3	Posterior notches
Sculpsitechinus tenuissimus	2a/2b	12	4	16	4-6	2-3	posterior lunules; L11=11-26; ß =66,5°; WA=32,5 TL

Table 14. Comparison between different species here studied. Data L1-3 in % TL.

III. SYSTEMATICS

In this chapter we will discuss the species and taxonomic groups that have been modified or proposed as a consequence of our observations. Others, such as *Amphiope* and *Astriclypeus* remain unaltered and are not considered / modified by us.

Family Astriclypeidae include the genera: *Astriclypeus* Verrill, 1867; *Amphiope* L. Agassiz, 1840; *Echinodiscus* Leske, 1778; *Paraamphiope* genus novum; *Sculpsitechinus* n. g.

Class ECHINOIDEA Leske, 1778
Subclass EUECHINOIDEA Bronn, 1860
IRREGULARIA Latreille, 1825
MICROSTOMATA Smith, 1984
NEOGNATHOSTOMATA Smith, 1981
Order CLYPEASTEROIDA L. Agassiz, 1835

Suborder SCUTELLINA Haekel, 1896
Infraorder SCUTELLIFORMES Haekel, 1896
Superfamily SCUTELLIDEA Gray, 1825
Family ASTRICLYPEIDAE Stefanini, 1912

Main characters of the family ASTRICLYPEIDAE

1. Main visceral central hollow, with floor reinforced by a network of thin trabeculae or by solid calcitic masses in apparently calloused form; peripheral buttressing developed as dense honeycombed meshwork of cellular structure;
2. Central or sub-central apical system with 4 gonopores;
3. Width of ambulacral and interambulacral zone at ambitus depends on the species or genera
4. Petals well developed and closed or nearly closed distally, sometimes open;
5. Small basicoronal circlet, with the interambulacral elements usually pointed, but not strongly

projected distally; all interambulacra disjointed or virtually disjointed on the oral surface;

6. Posterior interambulacral area always disjointed adorally and separated by enlarged first pair of post-basicoronal ambulacral plates;

7. Periproct oral open, along the perradial suture of the post-basicoronal plates in inter. 5;

8. Perradial lunules or notches in some or all ambulacra;

9. Food grooves well developed, bifurcated at the edge of the basicoronal circlet and branched distally.

From Smith & Kroh (2011, accessed September 2013), as emended.

Genus *Echinodiscus* Leske, 1778

=*Echinoglycus* Leske, 1778, p. 197 (nomen nudum)
= *Lobophora* Agassiz, 1841, p. 64, not Curtis, 1825 in Smith & Kroh (2011).
=*Tretodiscus* Pomel, 1883, p. 71 (objective)
=*Tetrodiscus* Lambert & Thiery, 1921, p. 323 (nomen vanum) from Smith & Kroh (2011).

Species included

E. formosus Yoshiwara, 1901, Middle ?Eocene, Miocene, Taiwan

E. pedemontanus (Airaghi, 1899), Rupelian, Italy

E. chikuzenensis Nagao, 1928, Oligo-Miocene, Japan

E. yeliuensis Wang, 1982, Early Miocene, Taiwan

E. bisperforatus Leske, 1778, Pleistocene-Recent, Indo-Pacific

E. andamanensis n. sp., Recent, Indo-Pacific;

E. truncatus (L. Agassiz, 1841), Recent, Indo-Pacific

E. desori Duncan et Sladen, 1883, Miocene, India

Echinodiscus sp. 1, Rupelian, Italy

Echinodiscus sp. 2, Pleistocene-Holocene, Egypt

Other species attributed to this genus, that need to be revised

Echinodiscus placenta Duncan et Sladen, 1883, Miocene, India

Echinodiscus ellipticus Duncan et Sladen, 1883, Miocene, India

Echinodiscus ginauensis Clegg, 1933, Saudi Arabia and the Persian Gulf

Diagnostic features

1. Test sometimes slightly indented laterally in ambulacra II and IV; thin and sharp margin;

2. Main visceral central hollow with floor reinforced by a network of thin trabeculae;

3. Petals sometimes open; the posterior pair shorter than the rest, the anterior odd sometime being the longest;

4. Posterior ambulacra with axial ellipsoidal lunules, long slit-like lunules or notches;

5. Periproct open next to the rear margin on inter. 5;

6. Food grooves branched distally;

7. Angle between the lunules from 70 to 110°;

8. Width at ambitus of interambulacrum 5 from 36 to 53% TL;

9. Tube-feet extending into interambulacral zones;

10. Post-basicoronal plates 2a/2b, 3a/3b on inter. 5 large and paired, forming an obtuse triangle;

11. Only 2–4 plates present between the lunules and the tips of respective petals.

From Smith & Kroh (2011, accessed September 2013), as emended.

Echinodiscus is distinguishable from the other genera, by the first two couple of post-basicoronal plates in inter. 5 large and paired, whereas in *Amphiope* and in *Paraamphiope* n. g. they are staggered, with the first one elongated and in *Sculpsitechinus* they are smaller and only partially paired; furthermore, the contact of the first post-basicoronal plates in inter. 5 and the related ambulacral is meridoplacous in *Echinodiscus*, while in *Amphiope* and *Paraamphiope* these is amphiplacous. *Echinodiscus* is distinguished from *Sculpsitechinus* as having only 2–4 couples of plates between the lunules and the tips of respective petals, instead of 3–6, and by the periproct position, which is very close to the posterior margin (2,5–13% TL) while it is more distant in *Sculpsitechinus* (11–26% TL).

Echinodiscus andamanensis n. sp.
Plate 15 Figs. 1–5, Table 12.

SYNONYMY. The synonymy includes only the citations that certainty belong to this species.
1971, *Echinodiscus tenuissimus* L. Agassiz, 1847, Clark A.M. & Rowe F.W.E, pp. 144–145

1987, *Echinodiscus tenuissimus* L. Agassiz, 1847, Bussarawit S. & Hansen B. (n.v.)

1991, *Echinodiscus tenuissimus* L. Agassiz, 1847, Warén A. & Crossland M.R., p. 106

2004, *Echinodiscus tenuissimus* L. Agassiz, 1847. Putchakam S. & Sonchaeng P., p. 424, pl. 1

2005, *Echinodiscus tenuissimus* L. Agassiz, 1847. Van der Steld b., Electronic Web Publ., accessed sept. 2013

EXAMINED MATERIAL. Holotype: specimen from Pak Meng Beach, Trang Province, Thailand, inventory n° PMBC 26346.1 TL 81 mm. Other specimens from Andaman coast of Thailand housed in the PMBC, Phuket, Thailand: PMBC.2842, TL = 66 mm, from Pak Meng Beach; PMBC.2843, TL = 66.2 mm and PMBC.2830, TL = 54.6 mm, from Noparat Tara Beach, Krabi Province; PMBC.2844, TL = 66.2 mm, from PMBC Jetty-South, Phuket Province. The series fromPak Meng Beachincludes 5 specimens, inventory numbers 2842.1-5, TL 65.8–79.2 mm. 1 specimen from West side of Ko Yao Yai, Phuket, housed in the NHMD.Z n° ZMUC-ECH-1001, TL 37 mm (See also Warén & Crossland, 1991 figs. 10a, c); 1 specimen from "Thailand", Recent (based on a illustration in "www. Echinoids NL"). In the latest specimen the TL is unknown, but the platings are well legible. The PMBC material was collected by S, Bussarawit and C. Nielsen, in 1975-1980, on sandy mud, at low tide and (PMBC jetty-South) on reef flat, sand.

DESCRIPTION. Small size, depressed test. Ambitus outline sub-rounded (TW ≈ 105 ÷ 110% TL). Oral surface flat, peristome sub central. The inter. 5 has 2 post-basicoronal plates per column, the first two large and triangular, the second one larger, forming the complex a broad-based triangle; the width at the ambitus is ≈ 38% TL. The periproct is very close to the rear edge (L11 = 6.6 % TL) and small (2 ÷ 3% TL), and it opens along the suture between the first two post-basicoronal 2b/2a plates or between 2b/2a/3a, in the samples examined (Plate 15 Figs. 1–5). The peristome is round and large size (almost 5% of the TL); the basicoronal ambulacral circlet is small (L13 = 10% TL). The petals are closed, the odd petal is longer than the other; petalodium size 49 % of TL. The lunules are short and axial (L1 = 14 % TL), narrow (L2 = 5.4 % TL) and with a ß of 75.5°. Each lunule is separated from the corresponding petal tip by 2-3 couples of plates and surrounded by

3-5 couples of plates per column on the aboral face, and by 3–4 on the oral one. The apical disc is star-shaped and small in size (≈ 8–10% TL). The internal structure and the size of the Aristotle's lantern were not detected. However, the complete plating was detected (Plate 15 Figs. 3, 4). The number of plates per column is shown in tab. 6. The food grooves are simple (Plate 15 Fig. 5); the main food grooves run through the center of each ambulacral column, starting from long stretches parallel to the ambitus. The distribution of tuberculation is linked to the shape and distribution of the food grooves. Large tubercles can be found in the basicoronal interambulacral plates and along the sutures that lead to the post basicoronal plates. Large tubercles also cover the periphery of the post basicoronal interambulacral plates, moving up the ambitus where the tubercles are smaller. Medium sized tubercles also cover a band along the perradial ambulacra sutures and close to the lunules toward the stoma, and the periproct; the tuberculation is apparently absent along the main food grooves. On the aboral face the tuberculation is undifferentiated, evenly distributed, dense and small, all over the surface in all the specimens.

ETIMOLOGY. From Andamane coasts of Thailand, locus typicus.

DISTRIBUTION. Recent, Thailand coast of Andamane Sea, Noparat Tara Beach, Krabi Province; Pak Meng Beach, Trang Province; PMBC jetty-South, Phuket Province. The type locality is Trak Meng Beach, Trang Province, Thailand 7°29'57.69" N, 98°49'08.51" E, on sandy mud, low tide.

COMPARATIVE NOTES. *E. andamanensis* n. sp. differs from *E. pedemontanus* in that all of its petal are closed, the periproct is rounded in shape, instead of drop-shaped, and in that the periproct opens between plates 2a/2b, against 3b/3a, in oral interambulacrum 5; moreover, *E. andamanensis* n. sp. differs from *E. bisperforatus* due to the shape of the lunules, that are longer and twisted in the last one and due to the ß angle that is 75.5° against 110°. *E. andamanensis* n. sp. have the WA at inter. 5 equal to 38% TL against 50% of *E. bisperforatus. E. andamanensis* n. sp. differs from *Echinodiscus* sp. 1 by the size of the stoma that is large (=>4 % TL) while in *Echinodiscus* sp. 1 is very small (<2.5% TL) and by the position of the periproct, which lies between 2a/2b in inter. 5, instead between 3a/3b. Furthermore, *E. andamanensis* has 5–7 aboral
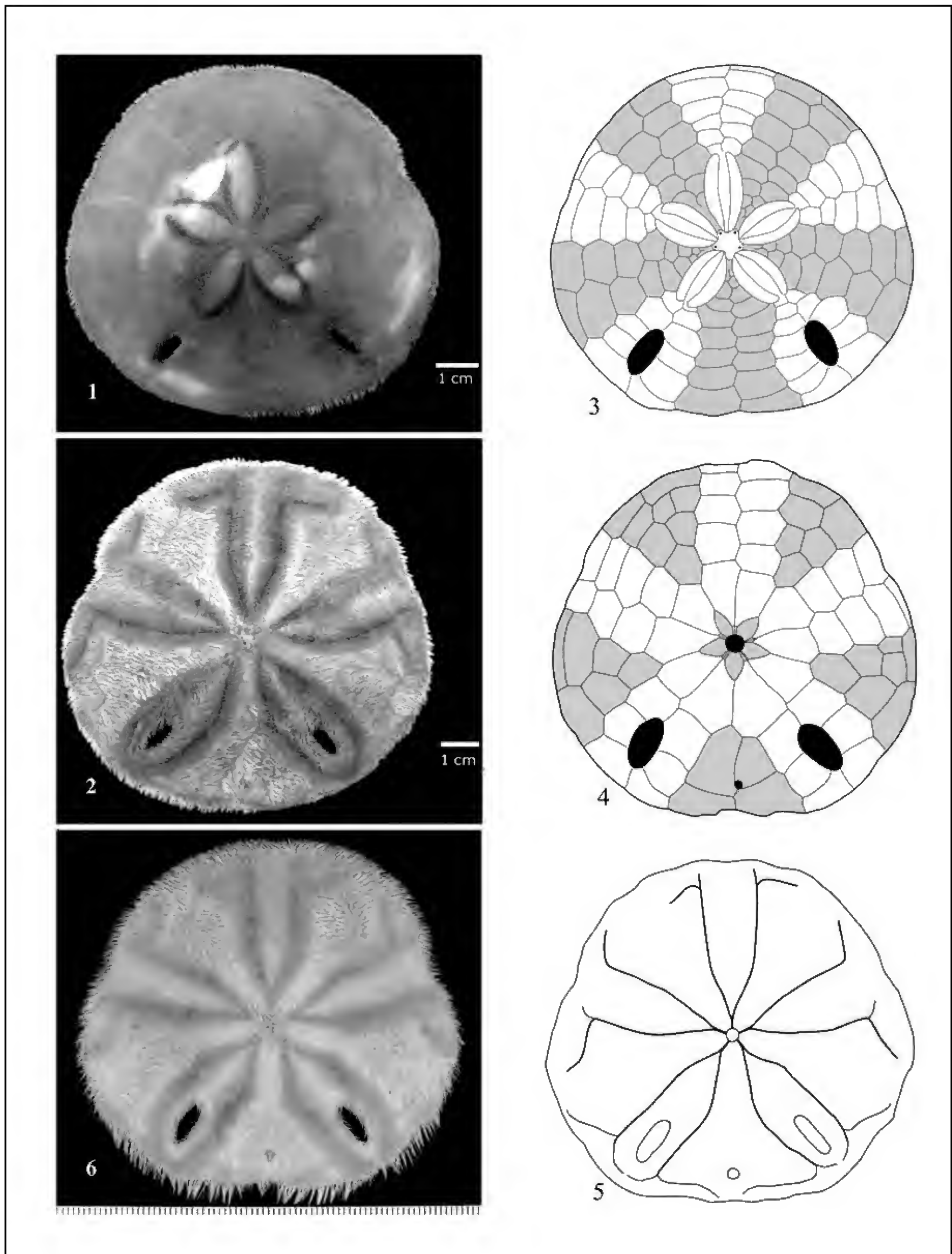
Plate 15. *Echinodiscus andamanensis* n. sp., Recent, Andaman coasts of Thailand. Figs. 1, 2. Aboral and adoral face of holotype PMBC.26346, from Pak Meng Beach. Figs. 3, 4. Aboral and oral plating pattern of specimen ZMUC-ECH-1001. Fig. 5. Food grooves scheme of specimen in Van Der Bas. Fig. 6. Oral face of PMBC.2643.1, from Noparat Tara Beach, in which are well visible the long coronal spines

couples of plates in the ambulacra I and V against 9-9. *E. andamanensis* n. sp. differs from *E. truncatus* in having the stoma much wider, spines much denser and longer (4.9 % TL against 3% TL) and simpler food grooves. Finally, *E. andamanensis* differs from *Echinodiscus* sp. 2 in having the periproct that opens between plates 2a/2b instead 2a/3b/3a.

Echinodiscus pedemontanus (Airaghi, 1899; pl. XXII, IV, fig. 4)
Plate 16 Figs. 1–8; Figs. 2a, b; Tables 3, 6, 8, 9

1899, *Amphiope pedemontana* Airaghi, p. 17, pl. VI, fig. 4a, b.
1901, *Amphiope pedemontana* Airaghi, p. 188, pl. XXII (IV), fig. 4.

TYPE SPECIMENS. The whole type-series, located at the Natural History Museum of Milan, was lost in the bombing during the last World War. The samples we studied are housed at the Museo di Storia Naturale "G. Doria" of Genoa (MSNDG) and one at the MAC, Cagliari. The sample inventoried with the number MSNDG.1218 is assigned as Neotype.

EXAMINED MATERIAL. Three specimens: MSNDG.25 from Pareto, MSNDG.1214 from Cairo Montenotte and MSNDG.1218 lacking indication of the locality; one specimen MAC.PL2014 from Merana (Alessandria Province). Illustrations of the samples described by Airaghi (1899 and 1901) were also examined.

EMENDED DIAGNOSIS. Species of medium-small size, depressed lateral profile, narrow and elongated axially lunules on the posterior ambulacra. Frontal odd petal slightly longer than the others and always open. In the oral face on inter. 5 there are only two pairs of post-basicoronal plates, with the first two large and paired.

DESCRIPTION. Small-medium sized, with more or less axially elongated lunules on posterior ambulacra. Depressed test (mean TH = 12% TL) with the highest point anterior to the apical disc. The margin is thin and uniform; ambitus rounded in outline and wider posteriorly. The frontal odd petal is slightly longer than the others and is open or almost open; the other one tends to be open, and the two rear ones are the shortest. Interporiferal and poriferal areas raised; sometime the poriferal zone is slightly

sunken, with the first ones 1 to 1.5 times larger than the others. The lunules are small (mean WI = 10.4), more elongated along the axis of the posterior ambulacra and narrow (mean SI = 0.37).

Only two post-basicoronal plates are present in each column on the oral inter. 5, with the first two plates being large and paired. The WA of inter. 5 at ambitus is, on average, 35% TL; on MAC.PL2014, the only one not deformed; ß is 93°. The periproct is small, elongated and drop-shaped (wide 2.2% and long 3.5% of TL), close to the posterior test margin and open between plates 2a/3b/3a or 3b/3a. Internal structure and other features as for the genus.

DISTRIBUTION. Type locality and horizon. Val Bormida, Liguria and Piedmont. Molare Formation, Rupelian. Occurrence in Italy: Dego, Mioglia, Pareto, Squaneto, Santa Giustina, Giusvalla, Cairo Montenotte, Merana.

COMPARATIVE NOTES. *E. pedemontanus* differs from *E. bisperforatus*, *E. andamanensis* and *E. truncatus* in the shape of the front odd petal, which is always open, and the periproct position that opens more posteriorly, between the second two postbasicoronal plates; it also differ from *Echinodiscus* sp. 2 from Hurgada (Egypt) in the petals shape. *E. pedemontanus* differ from *E. bisperforatus* in the shape and length of the lunules; on the ß angle that is 86° against 110°. Finally, *E. pedemontanus* have subequal petals and simpler food grooves, while *E. bisperforatus* have the front odd petal longer and the posterior petals always much shorter than the others and much complex food grooves.

Echinodiscus sp. 1
Plate 17 Figs. 1–6; Fig. 2c; Tables 3, 6, 8, 9

EXAMINED MATERIAL. Two specimens: UNIGE. SM-VI-P-(5)-DN and UNIGE.SM-VI-DR and two large fragments: UNIGE.SM-DS and UNIGE.SM-VI-VI-DP.

DIAGNOSIS. Small-medium sized species, with a depressed lateral profile and axially elongated lunules in the posterior ambulacra. Petals sub-equal, large and closed, the frontal one a little longer than the others. In the oral face on the inter. 5, there are only two post-basicoronal plates per column, large and paired. In the rear margin there is a clear notch that arrives close to the periproct.
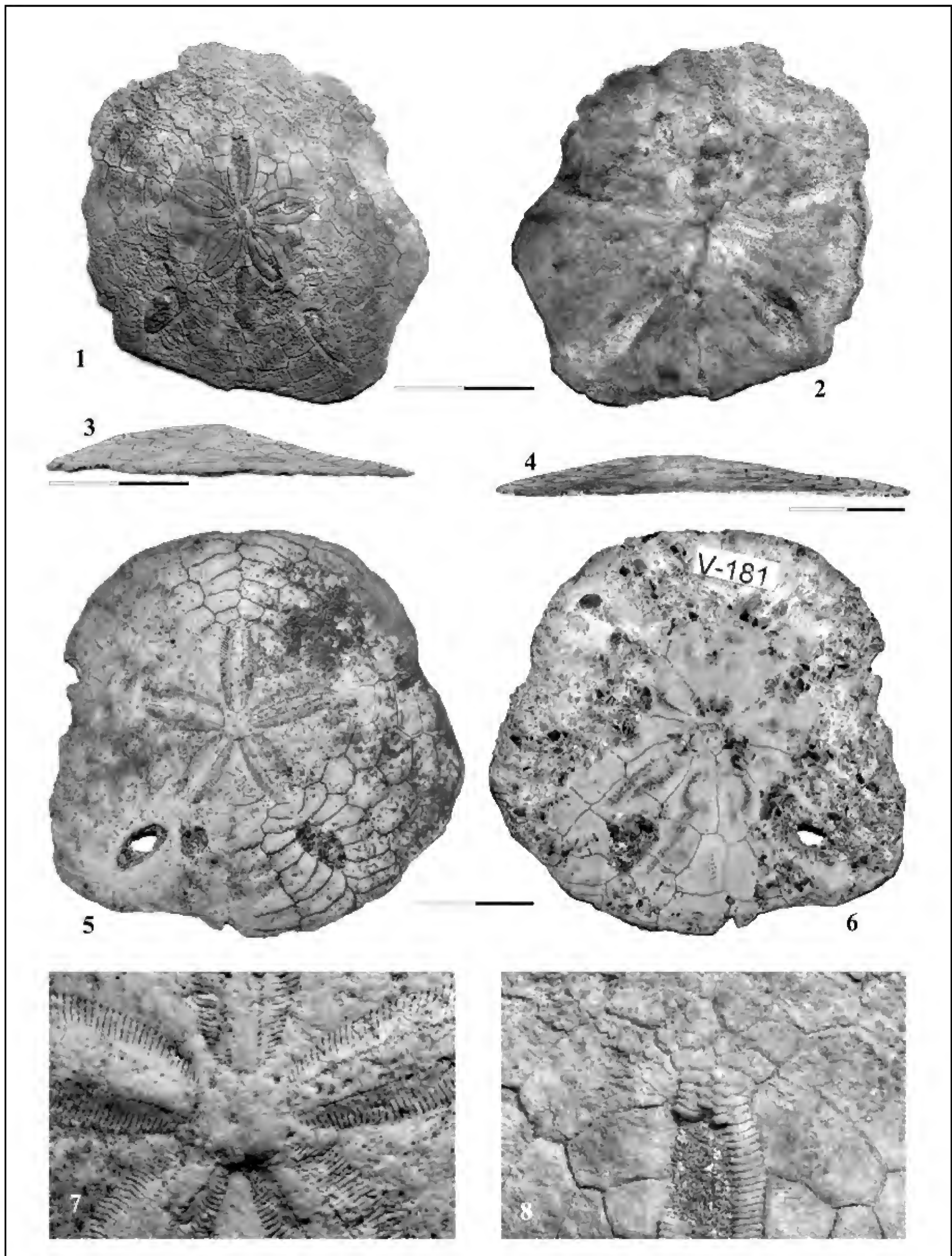
Plate 16. *Echinodiscus pedemontanus* from Liguria and Piedmont, Italy (Oligocene). Figs. 1–3. Aboral, adoral and antero (to the left)-posterior (to the right) lateral view of MSNDG 1218. Fig. 4. Antero (to the left)-posterior (to the right) lateral view of MAC.PL2014. Figs. 5, 6. Aboral and adoral view of MAC.PL2014. Fig. 7. Apical disc close-up of MAC.PL2014. Fig. 8. Magnification of open frontal odd petal in MSNDG 1218.

DESCRIPTION. Small-medium sized, with more or less axially elongated lunules in posterior ambulacra. Depressed test (TH = 10.5% TL) with the highest point anterior to the apical disc. Thin margin, anteriorly a little thicker than the rear. The ambulacra have sub-equal petals, closed, with poriferous and interporiferous zone similar in width. Small and narrow lunules, elongated along the axis of the posterior ambulacra. There are only two post-basicoronal plates per column in inter. 5; the first two are large and paired. The periproct is small (width = 2.5% of the TL) and round; close to the posterior margin and open along the suture between 3b-3a. The internal structure and other features as for the genus.

DISTRIBUTION. Locality and horizon: Val Bormida, Liguria and Piedmont, Molare Formation, Rupelian. Occurrence: Pareto e Santa Giustina (Liguria) Italy.

COMPARATIVE NOTES. *Echinodiscus* sp. 1 differs from *E. pedemontanus* in having all the petal closed, by the periproct shape, sub-rounded instead of drop-shaped, and by the characteristic indentation on the posterior margin of the interambulacrum 5, absent in all other known *Echinodiscus*. *Echinodiscus* sp. 1 differs from *E. bisperforatus* in shape, length and angle of the lunules. In *Echinodiscus* sp. 1 ß is 93° against 110° of *E. bisperforatus* and the WA at inter. 5 is only 35%, against 50% TL. *Echinodiscus* sp. 1 differs from *E. andamanensis* because in the last one the stoma is very large (> 5% of the TL) and by the position of the periproct, which lies between the plates 2a/2b in the inter. 5. Furthermore, *E. andamanensis* has 5-7 aboral couples of plates in the ambulacra I and V against 9-9. *Echinodiscus* sp. 1 differs from *E. truncatus* in having the periproct that open between the plates 3b–3a, while in *E. truncatus* it opens between plates 2b/2a/3b.

REMARKS. The specimen is inventoried as UNIGE.SM VI (P5) DN, and consists of a small-medium sized specimen (TL = 76 mm, TW = 104% TL, TH 8 mm), with both faces visible.

Echinodiscus sp. 2
Plate18 Figs. 1–3, 6; Plate 8 Figs. 3, 4; Tables 9, 12

EXAMINED MATERIAL. 1 specimen, MAC.PL 1850, TL = 21 mm.

DESCRIPTION. Small size echinoid, very flat test and thin ambitus, with rounded to sub-rounded outline. In the inter. 5 there are two plates per column, paired and wide. The ß angle is 80°, the axial lunules are narrow; the periproct opens between plates 2a/3a/3b. The anterior odd petal are the longest and the two posterior pair are shorter. Internal structure not detected.

DISTRIBUTION. Locality and horizon: Pleistocene-Holocene from Hurghada, Red Sea, Egypt.

REMARKS. *Echinodiscus* sp. 2 differs from *E. pedemontanus* in that all of its petal are closed, the periproct is rounded in shape, instead of drop-shaped; *Echinodiscus* sp. 2 differs from *E. bisperforatus* by the shape and size of the lunules, that are longer and twisted in the last one and due to the ß angle that is 80° against 110°. *Echinodiscus* sp. 2 differ from *Echinodiscus* sp. 1 by the size of the stoma that is very large (> 5% TL) while in *Echinodiscus* sp. 1 is very small (<2.5% TL) and by the position of the periproct, which lies between 2a/2b on oral interambulacrum 5, instead between 3a/3b. *Echinodiscus* sp. 2 differs from *E. truncatus* in having the stoma much wider and simpler food grooves.

Echinodiscus truncatus (L. Agassiz, 1841)
p. 66; pl. 11, figs. 11–16
Plate18 Figs. 4–6; Figs. 4a, b, Figs. 3, 4; Tables 9, 12

1841, *Lobophora truncata* L. Agassiz, pp. 66–67, pl., 11, fig, 11-16
1855, *Echinodiscus truncata* Gray, p. 20 (n.v),
1872, *Echinodiscus truncatus* Gray, Gray, p. 122 (n.v)
1921, *Amphiope (Tetrodiscus) laevis* Klein (Mellita), Lambert J. & Thiéry P., p. 323
1948, *Echinodiscus bisperforatus truncatus* (L. Agassiz), Mortensen, pp. 410-411, pl. 71, figs., 6, 18
1914, *Echinodiscus bisperforatus* var. *truncatus* Clark H. L., p. 42
1925, *Echinodiscus bisperforatus* var. *truncata* (L. Agassiz, 1841) Clark H.L., p, 171
1981, *Echinodiscus bisperforatus truncatus* (L. Agassiz, 1841) Dollfus R. & Roman J., p. 102, data (n.v. 1855-1872 taken from Kroh, A., 2012)

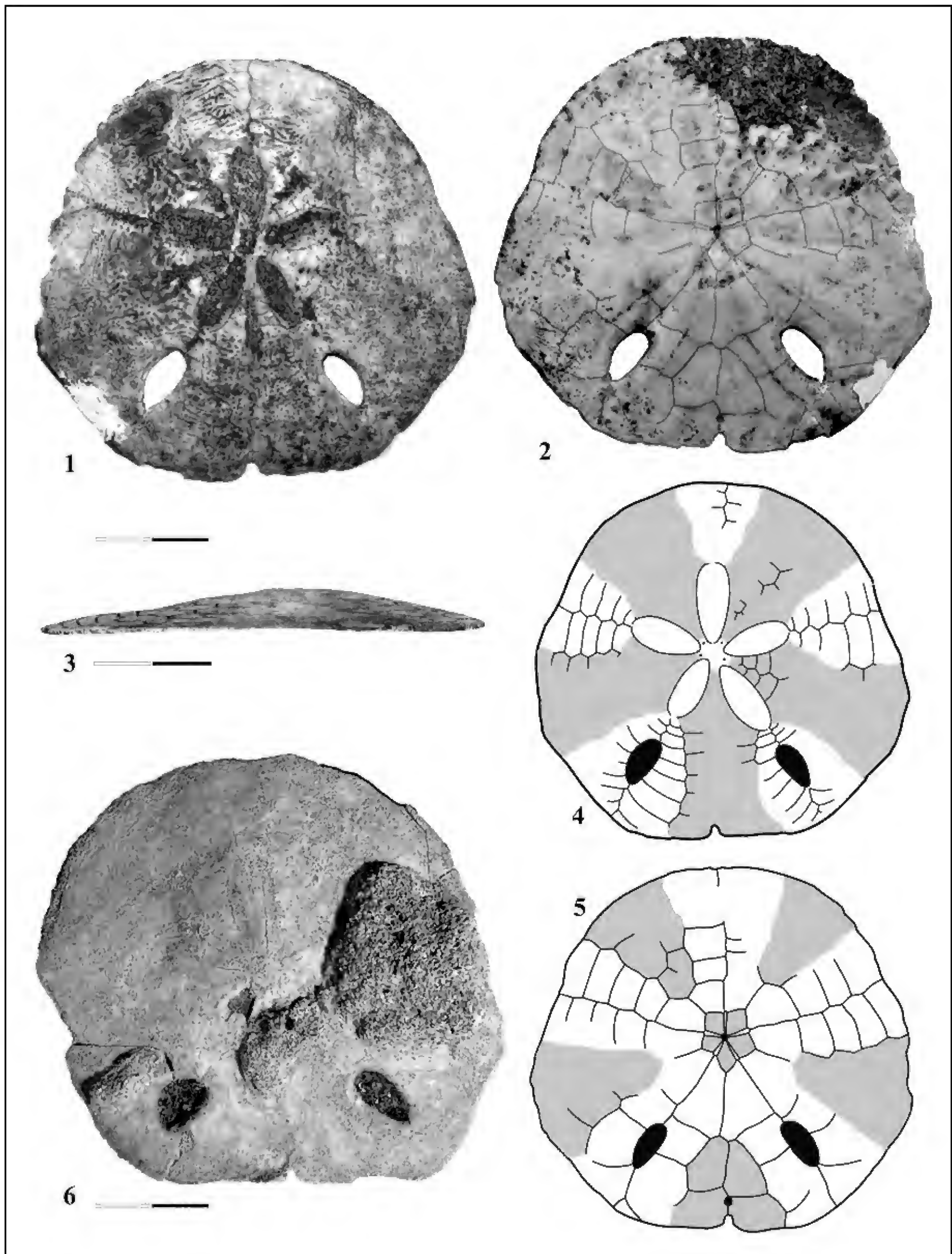EXAMINED MATERIAL. 2 specimens from Changi East coast, Singapore, in the Fantin collection: 137,

Plate 17. *Echinodiscus* sp. 1 from Liguria Italy (Oligocene). Figs. 1–3. Aboral, adoral and antero (to the left)-posterior (to the right) lateral view of UNIGE.SM VI (P5) DN. Figs. 4, 5. Aboral and adoral plate pattern of UNIGE.SM VI (P5). Fig. 6. Aboral view of UNIGE.SM-VI-DR. Figs. 2, 5. Despite the large deformations and distortions of lunules and shell, the generic characters remain intact and legible in the plate pattern of oral interambulacrum 5.

137A, TL = 51 and 60 mm (Plate 18 Figs. 4–6); three specimens from Kampong Pasir Ris, North East, Singapore; based on pictures from Ria Tan (web site www.wildsingapore.com, 2014); named S.1-3, TL unknown, but complete of spines.

DESCRIPTION. Small-medium size echinoid, flat test and thin ambitus with sub-rounded outline truncated at the posterior edge. The apical disc is eccentric forward (L4 = 57% TL; L 13 small (mean = 14% TL). In the inter. 5 there are two plates per column, paired and wide. ß is 67° on average; the WA vary from 37 to 40% TL. The lunules are axial and slit - like in shape; SI vary from 0.19 to 0.28 (mean = 0.22) and WI is 8.68 on average. The periproct is small and opens between plates 2b/2a/3b,with L11 on average 10% TL. The petals are sub-equal in size and PL is about 50% TL long. The food grooves are finely branched in all the ambulacra (Plate 4 Fig. 4). The primary spines are short (about 3% TL) and sparse; the tubercolation is visible in Plate 18 Figs. 3, 5.

DISTRIBUTION. Locality and horizon: Recent, Singapore.

COMPARATIVE NOTES. *E. truncatus* differs from *E. andamanensis* n. sp. in having the stoma smaller, spines much sparse and shorter (3% TL against 4.9 % TL) and much branched food grooves; *E. truncatus* differs from *E. pedemontanus* in that all of its petal are close and the periproct is rounded in shape, instead of drop-shaped; *E. truncatus* differs from *E. bisperforatus* by the shape of the lunules, that are longer and twisted in the last one and due to the ß angle that is about 67° against 110°; *E. truncatus* differs from *Echinodiscus* sp. 1 by the size of the stoma that is very small (<2.5% TL) while in *Echinodiscus* sp. 1 is very large (> 5% TL) and by the position of the periproct, which lies between 2b/2a/3b in oral interambulacrum 5, instead between 3a/3b. *E. truncatus* differs from *Echinodiscus* sp. 2 in having the periproct that opens between plates 2b/2a/3b instead 2a/3b/3a.

REMARKS. Agassiz L. (1841: 66), named these species *Lobophora truncata* because the ambital outline truncated at the posterior margin; among other features this species showed well food grooves, more branched than in *E. bisperforatus*. In addition, the lunules are shorter and a bit larger than in *E. bisperforatus* (formerly *Lobophora bifora*), The specimen

described by L. Agassiz was deposited at the "Museum of Paris" but where it came from is unknown.

Clark H.L. (1914) cites seven specimens from New Caledonia and two from Penang (Malaysia), but we believe that the New Caledonia's specimens belong to *E. tenuissimus* group, In fact, the information in our possession, says that in New Caledonia there are not *E. bisperforatus* and *E. truncatus*, but only echinoids belonging from the *Sculpsitehinus tenuissimus* group (formerly *E. tenuissimus*), As distinctive features, Clark H.L. (1914) mentions short lunules and short petals.

The same author (p. 171) confirms that he has observed several specimens from New Caledonia and from Penang (Malaysia), but he "doubts" that these correspond to "*E. tenuissimus*", and says that these specimens "would look like" to *E. truncatus*.

Dollfus & Roman (1981) consider *E. truncatus* a variety of *E. bisperforatus* and cite (p. 102) Singapore as locality where the described specimens came from. All this shows how much uncertainty there is in the recognition of certain species without the use of structural characteristics.

Paraamphiope n. gen.

TYPE SPECIES. *Paraamphiope raimondii* n. sp.; the holotype is housed in the Department of Animal Biology and Ecology, University of Cagliari (UNICA).

DESCRIPTION. Diagnostic features:
1. Sub pentagonal visceral hollow width almost 47% TL;
2. Main visceral central hollow with wall reinforced by a network of thin trabeculae;
3. Petalodium small in size (from 42 to 47% TL); petals well developed and almost closed distally;
4. Posterior axial ambulacral lunules ellipsoidal or narrow slits;
5. 3 to 4 pairs of plates between petals and lunules;
6. Periproct open less than 13% TL from the posterior margin;
7. The first two plates in inter. 5 must be staggered with the 2b in amphiplacous contact with the post basicoronal ambulacral plates;
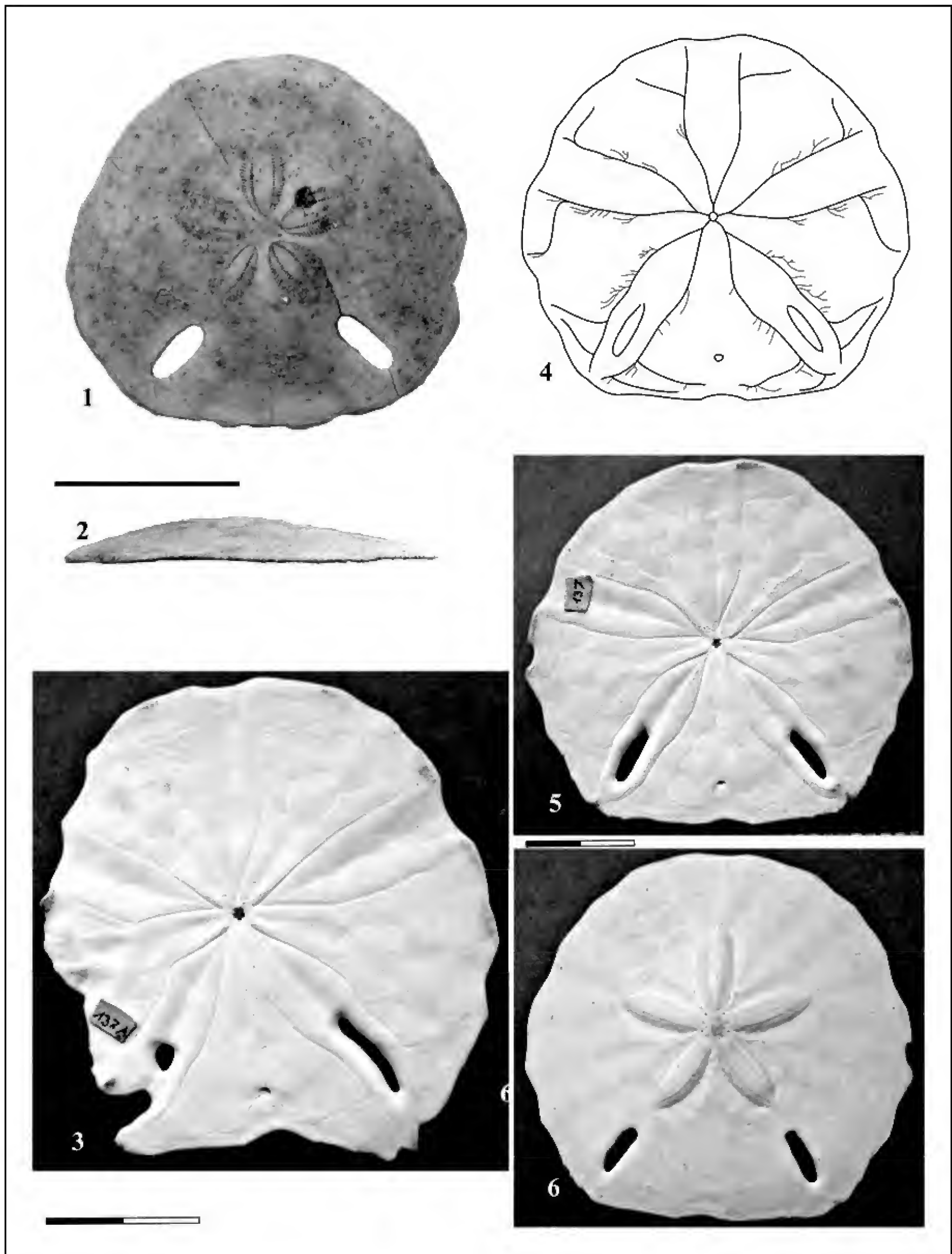8. Food grooves very branched distally near the rear edge;

Plate 18. Fossils and living *Echinodiscus* species. Figs. 1, 2. *Echinodiscus* sp. 2, aboral and antero (to the left)-posterior (to the right) lateral view of MAC.PL1850, from Hurgada, Egypt. Fig. 3. *Echinodiscus truncatus*, aboral face of malformed individual (specimen 137A from Fantin collection), Recent, Singapore. Fig. 4. Food groovers scheme of *E. truncatus* from Singapore. Figs. 5, 6. *E. truncatus*, oral and aboral view of specimen 137, from Fantin collection, Recent, Singapore.

9. width at ambitus at inter. 5 zone, measuring almost 36% TL;

10. ß angle about 88°;

11. Tube-feet extending into interambulacral zones.

ETIMOLOGY. Para = affinity with the relate genus *Amphiope*

DISTRIBUTION. From Libya and Indonesia, Miocene to Recent.

REMARKS. *Paraamphiope* n. g. differs from *Echinodiscus* in having the first two post-basicoronal plates of inter. 5 which are staggered whereas they are always large and paired in the second; moreover, in *Paraamphiope* n. g. the contact by post-basicoronal ambulacral plates in inter. 5 is amphiplacous, as in *Amphiope*, while this is meridoplacous in *Echinodiscus*. *Paraamphiope* n. g. differs from *Amphiope* in that has axial lunules separated by 3 to 4 couples of plates from the respective posterior petals, in the latter they are rounded or transverse and separated from respective petals tip by only 1-2 couples of plates; *Paraamphiope* n. g. has very branched food grooves in the posterior part of the test, in *Amphiope* they are very simple and in *Sculpsitechinus* these are highly branched and developed on the entire adoral surface. *Paraamphiope* have a petalodium long 42–46% TL, against 45-60% of *Amphiope* and 30–45% TL of *Sculpsitechinus*. *Paraamphiope* n. g. differs from *Sculpsitechinus* by the position of the periproct that is close to the rear margin (2.5–13% TL) against 11-26% TL.

This genus includes the following species:

P. raimondii n. sp., Recent, Indonesia (Borneo)
P. arcuata (Fuchs, 1882), Miocene, Egypt and Libya

Paraamphiope raimondii n. sp.
Plate 19 Figs. 1–7; Tables 9, 12

EXAMINED MATERIAL. Holotype, MAC.IVM 206, TL 53 mm housed in the Department of Animal Biology and Ecology (UNICA), Cagliari, Italy.

DIAGNOSIS. Small-medium sized species, with a low side profile and slit-like lunules axially elongated in the posterior ambulacra. Petals closed distally, with the front odd longer than the other and

the posterior ones slight shorter. In the oral inter. 5 there are 2 post-basicoronal plates in column "a" and 2 in column "b", with the first two ones staggered; between the petals and the notches there are 3 or 4 couples of plates, and the periproct opens along the suture between plates 2a/3b.

DESCRIPTION. Small-medium sized echinoid (TL 53 mm), with depressed test (TH = 11% TL) with the higher point anterior to the apical disc and a thin margin, rounded in outline. Petaloid medium size (42% TL); petals closed, with the frontal odd longer than the other. Poriferous zone flat, interporiferous ones slightly raised, with interporiferous size ranging from 1.5 to 2 those poriferous. Lunules axially, more long than large (L1 = 20 mm; L2 = 6.6 mm) and surrounded by 4 couple of plates on the aboral side and by 3 in the oral one. In the inter. 5 there are 2 couples of post-basicoronal plates, the first two 2b and 2a staggered and the 2b in amphiplacous contact with the first ambulacral postbasicoronal plates; in this interambulacrum the WA is 36% TL.

The periproct is small (3% TL) and sharply rounded, close the posterior margin (7% of TL) and open along the suture 2a/3b. Main visceral central hollow with wall reinforced by a network of thin trabeculae; peripheral buttressing developed as dense honeycombed meshwork of cellular structure; Aristotle's lantern width almost 27% of TL and large but short caecum cavity. The food grooves are very branched posteriorly; tubercolation well differentiated adorally, dense and poorly differentiated aborally (see Plate 19). Other data in relate Tables.

ETIMOLOGY. From the name of S. Raimondi, the collector that have donated the specimen to the museum.

DISTRIBUTION. Type locality and horizon: Recent, Indonesia (Borneo). Occurrence: Recent, Indonesia (Borneo).

COMPARATIVE NOTES. *P. raimondii* n. sp. differs from *P. arcuata* in the shape of the lunules and in the shorter distance of the lunules from the petals tip. Moreover, in the oral side of *P. arcuata*, the lunules open after two couples of post-basicoronal plates in ambulacra I and V, while in *P. raimondii* lunules open after only one couples of plates. Finally, the tubercles are absent or scarce along the perradial sutures in *P. raimondii* and are always present in *P. arcuata*.
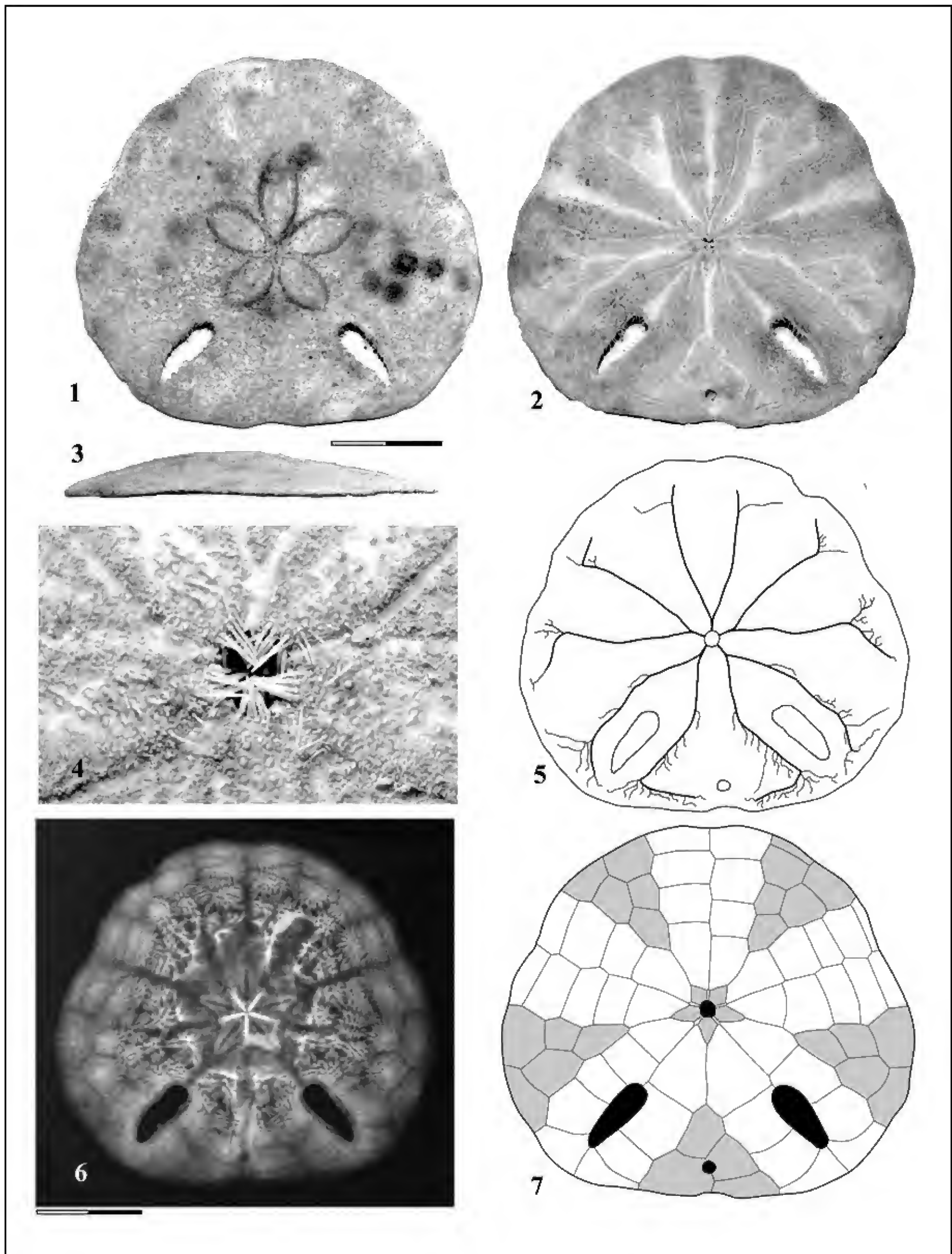
Plate 19. *Paraamphiope raimondii* n. sp., Recent, Indonesia. Figs. 1–3. Aboral, adoral and antero (to the left)-posterior (to the right) lateral view of MAC.IVM206. Fig. 4. Close-up of spines and tubercolation in the oral area. Fig. 5. Scheme of food grooves, more branched posteriorly. Fig. 6. Radiograph in supero-inferior projection with well visible support system and a large Aristotle's lantern. Fig. 7. Oral plate pattern.

Paraamphiope arcuata (Fuchs, 1882)
Plate 20 Figs. 1–6; Tables 6, 9

1882, *Amphiope arcuata* Fuchs, p. 31
1899, *Amphiope arcuata* Fuchs, Fourtau R., p. 698
1911, *Amphiope arcuata* Fuchs, Gregory, p. 667
1914, *Amphiope truncata* Fuchs, 1882, Cottreau, p. 55
1920, *Amphiope arcuata* Fuchs, Furtau, p. 40
1920, *Amphiope arcuata* Fuchs, Migliorini, p. 153

EXAMINED MATERIAL. The material studied by us is labeled as Miocene, Libyan desert (locality not specified), housed in the NHMUK in London, with code E1671-2, E1674-6, TL 35 ÷ 79 mm.

DIAGNOSIS. Small-medium sized species, with a low side profile and ovoid lunules axially elongated in the posterior ambulacra. Petals closed distally, sub-equal in size. In the oral face of the inter. 5 there are 2 post-basicoronal plates in column "a" and 2 (sometimes also a small part of the fourth plate is visible) in column "b", with the first two staggered; between the petals tip and the lunules there are 3 or 4 couples of plates, and the periproct opens between plates 2a/3b.

DECRIPTION. Size small-medium (in our sample max TL = 79 mm) as wide as long. Test depressed (TH = 6 ÷ 12% TL). The highest part of the test lies on the apical disc, which is sub-central. The ambitus outline is subrounded to subtrapezoidal; the adoral surface is flat or slightly plano-concave with the inner point near the peristome, which is sub-central. There are 2 post-basicoronal plates in column "a" and 2–3 in column "b", in which the 2b is wide and elongated (like as in *Amphiope*) and are in amphiplacous contact with the relate post-basicoronal ambulacrals. The periproct is small (2–3% TL) and opens between the post- basicoronal plates 2a/3b on inter 5; L11 varies from 4 to 14 % TL. The peristome is round and measure from 3.5% to 5.5 TL.

The petals are just closed in larger specimens, but the frontal odd seems open in the smaller specimen. The Petalodium is of medium size (42 ÷ 47 % TL). The lunules are very small and ellipsoidal shaped. The ß angles ranges between 88° to 96°. Each lunule is separated from the corresponding petal by 4–5 couples of plates and surrounded by

4–4 couples of plates on the aboral side, against 3–4 couples on the adoral one.

Apical disc with a small (≈ 6% TL) star-shaped madreporite, with 4 genital pores, all open also in the smaller individuals. Internal structure and size of Aristotle's lantern were not detected.

The main food grooves are simple and run through the center of each column in the ambulacra, starting from small branches parallel to the ambitus or from the ambitus itself (in E76164). Short secondary branches grow along the grooves on the posterior ambulacra and near the lunules and the periproct. Tubercolation is poorly differentiated on the oral face; tubercles are large on the basicoronal interambulacral plates and on the post-basicoronal ambulacral ones. In the interambulacra the tubercles diminished in size farther from the center; large tubercles surround the periproct. The tubercolation covers with small tubercles also major food grooves. On the aboral face the tubercolation is undifferentiated, evenly distributed, dense and petite, over the entire surface.

DISTRIBUTION. Libya, Miocene. Locality and horizon: Syouah, Gebel Ndefer, Egypt (the Holotype is housed in the Naturhistorisches Museum of Vienna) and Libyan desert (Tobruc area), Middle Miocene.

COMPARATIVE NOTES. Morphologically, *P. arcuata* differs from "*Amphiope*" *truncata* Fuchs, 1882, in its smaller size, smaller petalodium, lunules outline much more ovoids and the food grooves less branched distally; *P. arcuata* differs from *P. raimondii* n. sp. by the shape of the lunules and by the longest distance of the lunules from the petal tips. Moreover, the tubercles are always present along the perradial sutures while in *P. raimondii* are absent or scarcely.

REMARKS. Under careful observation of the specimen E76164, the rear part of the test seems incomplete and for this reason the measurements and plating are biased in this way. It is unclear whether this anomaly occurred before or during the process of fossilization.

The illustrations of the type species provided by Fuchs (1882: 31, pl. XI, figs. 4-6) correspond, from a morphological point of view, to the specimens studied by us. Cottreau (1914) puts this species in synonymy with *A. truncata* Fuchs,1882 and *A. fuchsi* Fourtau, from the Middle Miocene of Egypt, then,
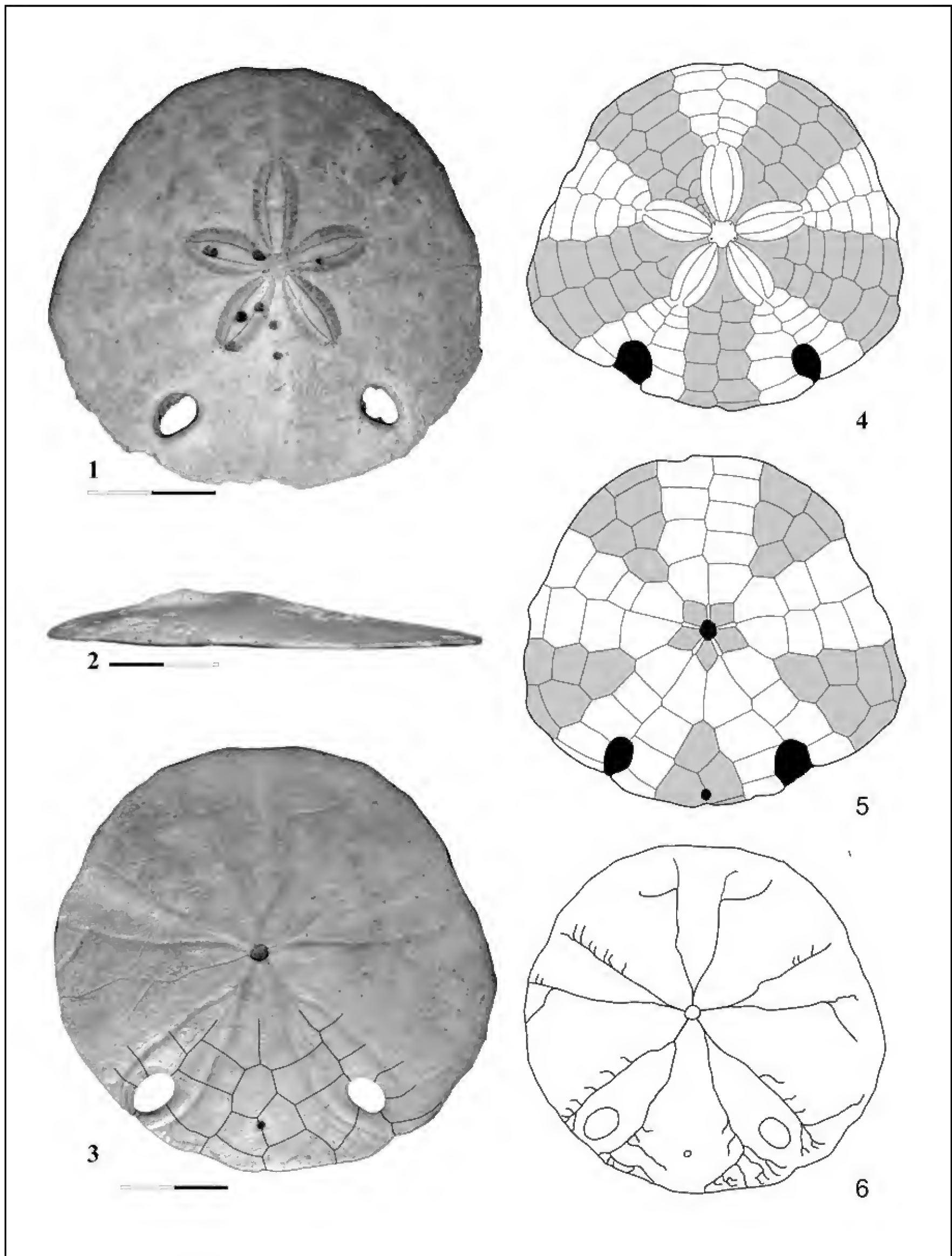
Plate 20. *Paraamphiope arcuata* from Libya (Miocene). Fig. 1. Aboral view of NHMUK.E76162. Figs. 2, 3. Antero (to the left)-posterior (to the right) lateral and adoral view of NHMUK.E76161. Fig. 4, 5. Plate pattern of aboral and adoral face of NHMUK.E76164. Fig. 6. Food grooves scheme of NHMUK.E76161. In this example it is evident the great outline variability, in particular in the rear of the ambitus, due (Figs. 4, 5), perhaps, to defects in fossilisation.

in figure 23 he illustrates *A. arcuata* as type. However, the scheme of the plates of the other nominal species has never been published, and therefore we believe that they should remain a separate species.

Sculpsitechinus n. gen.

TYPE SPECIES. *Sculpsitechinus auritus* (Leske, 1778)= *Echinodiscus auritus* Leske, 1778.

As Neotype are assigned specimen MAC. IVM109 and is housed in the Department of Animal Biology and Ecology, University of Cagliari (UNICA).

DESCRIPTION. Diagnostic features:

1. Subcircular or vaguely polygonal visceral hollow, with the floor reinforced by a network of ribs;

2. Petalodium small, PL about 30–48% of TL; petals always closed distally;

3. Pentastellate basicoronal circlet, with the interambulacral plates that can be elongated distally, usually separated from the post-basicoronal ones;

4. Posterior ambulacra with axial notches or lunules; the lunules shape may vary from ellipsoidal to narrow slits like, which may be open to the ambitus;

5. 3 to 6 couples of plates are present between petals tip and lunules/notches;

6. Periproct far from the rear margin almost 13 ÷ 26% of TL;

7. 3 or 4 post-basicoronal plates per column in inter. 5, with the first two partially paired and normally in meridoplacous contact with the relate ambulacrals;

8. Food grooves very branched and spread over all the oral surface;

9. Width at inter. 5 zone at ambitus about 30–38% of TL;

10. ß angle within 48° to 70°;

11. Tube-feet extending into interambulacral zones.

ETIMOLOGY. Sculpsit = carved: the name derives from the rear notches that characterized the species *Echinodiscus auritus* Leske, 1778, transferred here to *Sculpsitechinus auritus* (Leske, 1778).

DISTRIBUTION. From Indian Ocean, Red Sea, Persian Gulf to West-Pacific. Time span: from Middle Miocene to Recent.

COMPARATIVE NOTES. *Sculpsitechinus* n. gen. differs from *Amphiope* and *Echinodiscus* in that it has 3 to 6 pairs of plates between the posterior petals tip and the respective lunules, whereas there are only 1–2 in *Amphiope* and 2–4 in *Echinodiscus*; also the first two post-basicoronal plates in inter. 5 are relatively small and only partially coupled, in *Amphiope* and *Paraamphiope* they are always staggered, with the first one longer, and in *Echinodiscus* they are always large and paired. *Sculpsitechinus* n. gen. differs from the other genera also by the position of the periproct that is far from the rear margin (13–26% TL), while in the other ones this distance ranges from 2.5 to 13% of the TL. Furthermore, *Sculpsitechinus* n. g. differs from *Amphiope* also in having a smaller petalodium (30–47% against 45–60%). *Sculpsitechinus* n. g. differs from *Echinodiscus* by the smaller width of inter. 5 at the ambitus (30–38 against 35–54), and the lower angle between the lunules (ß = 54°–70° against 70°–117°). Finally, *Sculpsitechinus* n. g. differs from *Amphiope* and *Echinodiscus* by the food grooves highly branched on the whole adoral surface.

REMARKS. This genus includes the following species:

S. auritus (L. Agassiz, 1838); Recent; Tulear, Madagascar, Red Sea, Indian Ocean and West Pacific.

S. tenuissimus (L. Agassiz, 1847) Recent; Lembeh, North Sulawesi and Waigeo, West Papua (Indonesia); New Caledonia, Papua New Guinea and Palau, Micronesia.

Sculpsitechinus sp. 1; Recent; Bohol and Oslob islands, Philippines.

Sculpsitechinus sp. 2, Middle Miocene; Papua New Guinea.

Sculpsitechinus auritus (Leske, 1778)
Plate 21 Figs. 1–7; Tables 6, 9, 11, 12 (see also Table 3 in Stara & Fois D., 2014)

1778, *Echinodiscus auritus*, Leske N.G., p. 138
1778, *Echinodiscus inauritus* Leske N.G., p. 138
1816, *Scutella bifissa* Lamarck J.B.P.A., p. 10
1817, *Scutella bifissa* Savigny, pl. 7 fig. 3 (n.v)
1826, *Scutella bifissa* Lamarck, Auduin, p. 210 (n.v)
1841, *Lobophora aurita* L. Agassiz, pp. 70–71, pl. 14, figs. 3, 7

1892, *Echinodiscus auritus* Leske, Boutan L., p. 29, 46, 47

1893, *Echinodiscus auritus* Leske, de Loriol P, p. 375

1894, *Echinodiscus auritus* Leske, Mazzetti G, pp. 222, 225–226 (n.v)

1899, *Echinodiscus auritus* Leske, Fourtau R, pag. 540

1904, *Tetrodiscus auritus* Fourtau, pag. 425, 444 (n.v)

1914, *Amphiope* (*Tetrodiscus*) *aurita* Leske, Fourtau R, p. 88 (n.v.)

1948, *Echinodiscus auritus* Leske, Mortensen T., pp. 400–406

1955, *Echinodiscus auritus* Leske, Tortonese E., p. 38

1971, *Echinodiscus auritus* Leske, Clark A.M. & Rowe F.W.E., p. 144

1971, *Echinodiscus auritus* Leske, James D.B. & Pearce J.S., p. 99

1981, *Echinodiscus auritus* Leske, Dollfus R. & Roman J., pp. 97–99

2014, *Echinodiscus auritus* Leske, Stara & Fois M.

EXAMINED MATERIAL. Neotype: MAC.IVM.109, TL 125 mm, Recent, from Mangili, Tulear Province, Madagascar. Housed in the Department of Animal Biology and Ecology (UNICA), Cagliari, Italy. 31 specimens from Mangili, Tulear Province, Madagascar, caught in back-barrier lagoon, ≈ 5 to 8 m in deep, in sandy-mud, MAC.IVM82 - 113–1 TL = 74 ÷ 140 mm, housed in the Museo di Storia Naturale Aquilegia, Cagliari and in the Department of Animal Biology and Ecology (UNICA), Cagliari, Italy.

DIAGNOSIS. Medium sized species, with a low side profile and axially elongated notches in the posterior ambulacra. Petals closed distally, in a small petalodium. In the oral interambulacrum 5 there are 3 post-basicoronal plates in column "a" and 4 in column "b", with the first two partially coupled; between the petals tips and the notches there are 4 - 5 couples of plates, and the periproct opens along the suture between plates 2b/2a in interambulacrum 5.

DESCRIPTION. Medium-sized echinoid with a almost polygonal ambital outline; the posterior margin line, sited between the two notches (like a tail), is always irregular and often very asymmetric.

Although in smaller individuals a rounded outline seems to prevail, the larger individuals present clearly truncate lines; however the ambitus outline can vary greatly. The adoral face is flat or slightly plano-concave. The periproct is small and far from the posterior margin (L11 = 18–24% TL). The plating structure is reported in Plate 23.

In this samples the Aristotle's lantern measures about 15% TL. The petalodium is medium size (PL = 35–40% TL) and the petals are sub-equal, twice as long as the width and always closed (L5 = 18%; L7 and L9 = 17% TL); the poriferous areas are 1.2 to 1.5 times wider than the poriferous ones. The apical disc measures 6% TL. Only one pair of post-basicoronal ambulacral plates occlude the interambulacrum 5. The notches are surrounded by 4-5 couples of plates on the oral face and by 4-5 on the aboral one. Between the petal tip and the beginning of the notch there are 6 couples of plates per column. ß is approximately 55° and WA at interambulacrum 5 is on average 32% TL. In the oral side of the interambulacrum the periproct opens between post-basicoronal plates 2b-2a. The stoma is pentagonal, with a diameter of 4% TL; L13 = 11% TL. The basicoronal interambulacral plates are all irregular, with some in contact and others disjointed. The tuberculation is dense, made up of medium sized tubercles, poorly differentiated and extended over the entire aboral surface. The tubercles are larger around the periproct and the smaller ones are found particularly along the main food grooves. On the aboral face the tubercolation is undifferentiated, thick and petite, evenly distributed over the entire surface. The food grooves are very branched out over the entire oral surface.

DISTRIBUTION. Tulear, Madagascar; Indian Ocean, Red Sea, Persian Gulf, Oceania West-Pacific Ocean. Recent.

COMPARATIVE NOTES. *S. auritus* differs from *S. tenuissimus* and from *Sculpsitechinus* sp. 2, by having notches against lunules. *S. auritus* differs from *Sculpsitechinus* sp. 1, in having smaller Aristotle's lantern and greater size.

REMARKS. To establish this species, Leske (1778: 202), did not mention the locality where the specimens studied come from and neither the museum in which these specimen has been deposited. The author, however, has not even provided an illustration of the sample that he described.
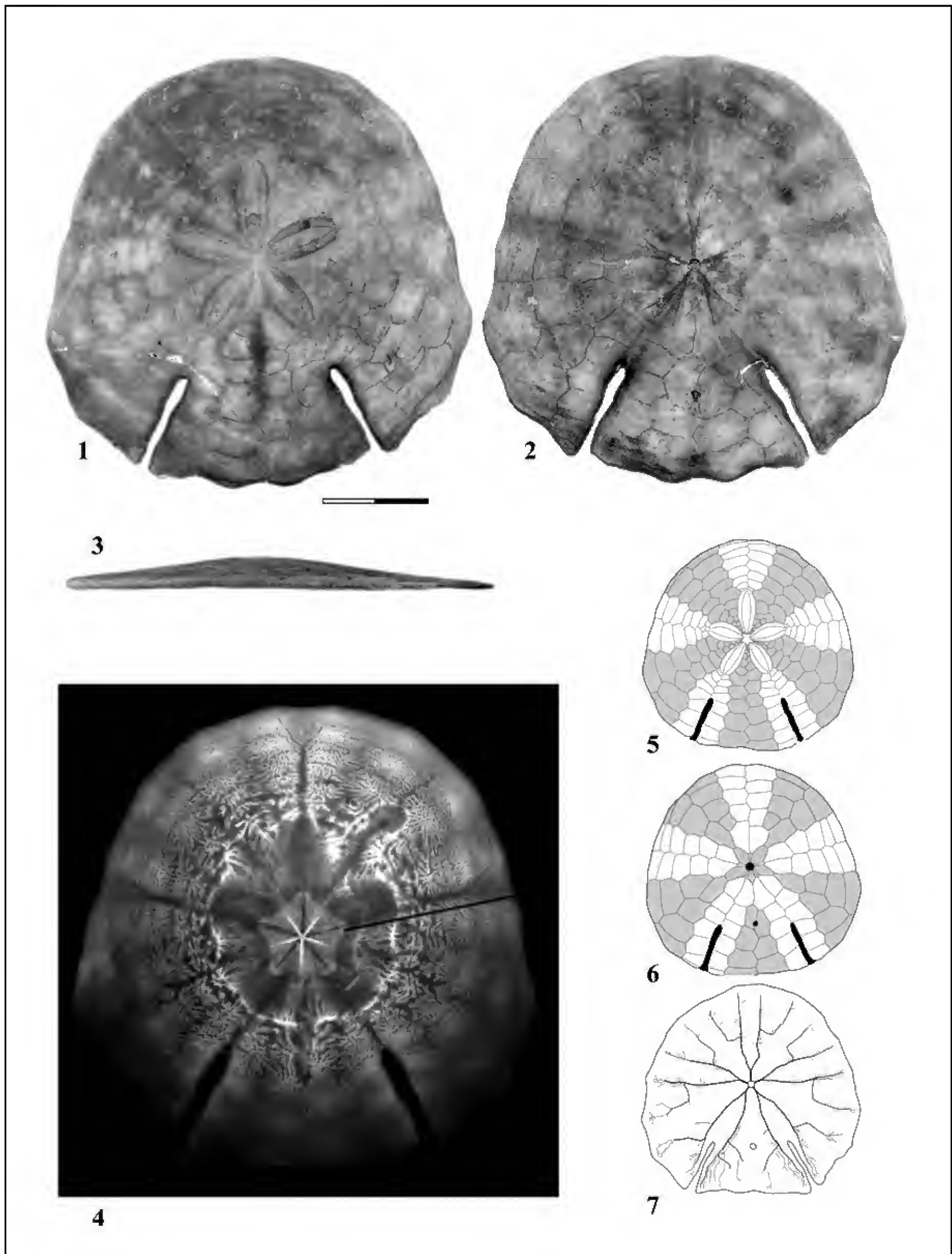
Plate 21. *Sculpsitechinus auritus*, Recent, Mangili, Madagascar. Figs. 1–3. Aboral, adoral and antero (to the left)-posterior (to the right) lateral view of MAC.IVM109. Fig. 4. Radiograph taken in super-inferior position of MAC.IVM109, in which is visible the small Aristotle's lantern. Figs. 5, 6. Plate pattern of aboral and adoral faces of MAC.IVM110. Fig. 7. Well branched food grooves scheme.

Despite our historical research, followed by a information request to the Natural History Museum in Leipzig, the city where Leske has worked for long time, we could not find the type specimens. Kindly, R. Schiller from the Museum of Natural History in Leipzig, communicated us (June, 17. 2014) that are not found in their museum specimens of the Leske's collection. Thanks to R. Schiller, R. Wolf, from the Zoologic Collection of the University of Leipzig has informed us that some of his old collections were dispersed in several other museums in Germany but they do not possess these samples. Our historical research will be continued but, being necessary to know some features that are not described by the first author, as the test plate structure, we felt it opportune to name as Neotype a specimen of *Sculpsitechinus auritus* (former *Echinodiscus* cf. *auritus* in Stara & Fois M., 2014) from Mangili, Madagascar.

Sculpsitechinus tenuissimus (L. Agassiz, 1847)
Plates 22, 23; Figs. 9a–c; Tables 6, 9, 12

1847, *Echinodiscus tenuissima* (L. Agassiz & Desor E.,)
1847, *Lobophora tenuissima* L. Agassiz & Desor E., p. 78
1861, *Lobophora deplanchei* Michelin (n.v.)
1863, *Lobophora texta* A. Agassiz, p. 359
1872–74, *Echinodiscus laevis* A. Agassiz (n.v.)
1881, *Echinodiscus biforis* Pfeffer (n.v.)
1948, *Echinodiscus bisperforatus* var. *truncatus*, Mortensen T., pp. 409, 411, 413
1971, *E. tenuissimus* Agassiz, 1847, Clark A.M. & Rowe F.W.E, p. 148
1986, *E. tenuissimus* Agassiz, 1847 De Ridder C. (n.v.)
Data (n.v. 1861-1881 taken from Kroh, A., 2014)

EXAMINED MATERIAL. The Type material is not traceable in the Museum of Natural History of Paris where it was housed (see Agassiz & Desor, 1847). For these reasons we had to establish a Neotype.

Neotype: one specimen from Lembeh Channel, North Sulawesi, Indonesia, MAC.IVM207, TL 50 mm (Plate 21 Figs. 1, 2, housed in the Department of Animal Biology and Ecology (UNICA), Cagliari, Italy.

Two specimens from Lembeh Channel, North Sulawesi, Indonesia, MAC.IVM207-208, and two from Fantin Collection TL = 50–60 mm; one specimen from New Caledonia, NHMUK.1981.11.2.25, TL 112 mm, TH 10.5 mm, one specimen from Palau, Micronesia, NHMUK.59.7.1.14, TL 120 mm, TH 11 mm. We have also considered a specimen from "New Caledonia" by literature in: Dollfuss & Roman (1981, table 33 figs. 5, 6), TL 121 mm; and one by personal communications and photos by F. Hattemberger collection, TL 68 mm, collected at the depth of 2 meter in a sandy beach from Noumea, Baie des Citrons, New Caledonia.

DIAGNOSIS. Medium sized species, elongated (in the specimens of New Caledonia and Palau) with a maximum width very rear of the center (mean TW = 97% TL), profile low, small and ellipsoidal-shaped to slit-like lunules. Petalodium highly variable (30 to 38% TL) smaller in the samples of New Caledonia and in those of North Sulawesi, the greater one in the specimen from Palau. In the oral face of the inter. 5 there are 2–3 post-basicoronal plates in column "a" and 3 in column "b", with 2a and 2b partially paired; between the petals and the lunules there are 4-5 couples of plates.

DESCRIPTION. Medium sized; small, narrow and elongated ambulacral lunules (L1 = 12% and L2 = 4% TL, with WI = 7.7 and SI = 0.33) and with a narrower angle ß (67 °). Depressed test (≈ 9% TL), with the most highly point anterior to the apical disc. Thin margin, more thick anteriorly. Sub-equal petals, closed distally, with the front one slightly longer than the others; interporiferal zone wider 1–1.5 times of the poriferous ones. In the inter. 5 there are 2-3 post-basicoronal plates in column "a" and 3 in column "b", with the first two partially coupled. The WA at the inter. 5 is 31% TL, one of the lowest among *Sculpsitechinus*. The periproct is small (2.5% TL), round shaped, far from the posterior margin (11 to 18% TL) and open between plates 2b/2a or 2b/3a/3b in inter. 5. The peristome is sub-pentagonal and small (3.5% TL), sub-central. Other features as for the genus. For any other data see the relate tables and plates.

DISTRIBUTION. Lembeh Channel, North Sulawesi; Waigeo, West Papua (Indonesia); New Caledonia, Papua New Guinea and Palau Sibuan, (Micronesia and Melanesia) and perhaps Japan. Recent.

COMPARATIVE NOTES. *S. tenuissimus* differs from *S. auritus* and from *Sculpsitechinus* sp. 1 in that it has lunules instead notches. *S. tenuissimus* differ from *Sculpsitechinus* sp. 2 by the SI index that is greater (0.33) against 0.18 of *Sculpsitechinus* sp. 2. The data, however, is not sufficient to separate with certainty this species, because the oral plate structure of *Sculpsitechinus* sp. 1 is still unknown.

REMARKS. As already mentioned in the paragraph on *Echinodiscus andamanensis* n. sp., not having been published the plating of the type species *Echinodiscus tenuissimus*, under this name are included several morphotypes based on the test and lunules shape, coming also from very different geographical areas. However, the description of the type species made by Agassiz & Desor (1847: 78) is really laconic "species very flat, with small lunules, corresponding to the ambulacra pair posterior" and the sample deposited at the time in the "Museum of Paris", is now wanting (pers. comm. Sylvain Charbonnier, June 03.2014). Agassiz & Desor (1847) mentions the geographical origin (Waigiou), which corresponds to New Britannia (Indonesia). In the zonation resulted from our observations, in this area only *Sculpsitechinus* species are present. It seems clear, therefore, the need to appoint a neotype from the closest geographical area.

***Sculpsitechinus* sp. 1**
Plates 1, 2; Table 1 in Stara & Sanciu (2014)

EXAMINED MATERIAL. 12 specimens, Recent, MAC IVM 81; MAC.IVM206 - MAC.IVM215; MAC.IVM233, housed in the MAC, Cagliari, Italy.
5 specimens from Oslob (TL 131 ÷ 154 mm), 5 specimens from Cebu (TL 152 to 173 mm); two examples of generic origin "Philippines" (TL 121 and 152 mm).

DIAGNOSIS. Large sized specie (up to 173 mm), with low side profile (mean TH = 12% TL), narrow and elongated ambulacral notches open on the posterior margin. Sub-equal petals, closed distally, with the frontal odd petal sometimes slightly longer than the other ones. In the oral face of the inter. 5 there are 3 post- basicoronal plates in column "a" and 4 in column "b", with the first two partially coupled

and the periproct that opens between the plates 2a/2b. Between the petals tip and the beginning of the notches there are 4 or 5 couples of plates.

DESCRIPTION. Large in size (in the studied sample TL 121 ÷ 173 mm), with more or less axially elongated ambulacral notches open on the posterior margin. Depressed test with the highest point anterior to the apical disc. Thin margin, more thick anteriorly. The petals are closed, sub-equal, with the frontal odd one a little longer than the other; poriferous zone flat or slightly sunken, interporiferous ones slightly raised, with interporiferous areas 1.5 to 2 larger than the poriferous ones. Notches varying in length from 18 to 27% of TL and are more or less narrow. The WA at inter. 5 is on average 33% TL and the ß angle is on average 57°. The periproct is small (2.5% TL), rounded in shape, far from the posterior margin (16–24% TL) and always open along the suture 2b/2a. The internal structure consists of a central visceral hollow and a peripheral support structure. The hollow is sub-rounded to polygonal shaped and its size corresponds to the petalodium length (PL ≈ 42% TL), the floor is thin and reinforced by a structure made by a network of thin trabeculae. The system of pillars and buttresses is similar to the *S. auritus*. the Aristotle's lantern is very large (20–24% of TL in specimen 140 mm long). For descriptive statistics see Stara & Fois M. (2014).

DISTRIBUTION. Island of Talibon (Bohol) and Island of Oslob (Cebu), Philippines. Recent.

COMPARATIVE NOTES. *Sculpsitechinus* sp. 1 differs from *S. auritus* by a larger Aristotle's lantern that measures 20–24% TL against 15-18% TL in a specimens 140 mm long. *Sculpsitechinus* sp. 1 differs from *S. tenuissimus* by a less number of couples of plates between petals tip and lunules/notches, which are 3–4 against 5-6 and have notches instead lunules.

***Sculpsitechinus* sp. 2**
Plate 14 Fig. 4

Based on the illustration in Lindley (2001:128, fig. 7d.

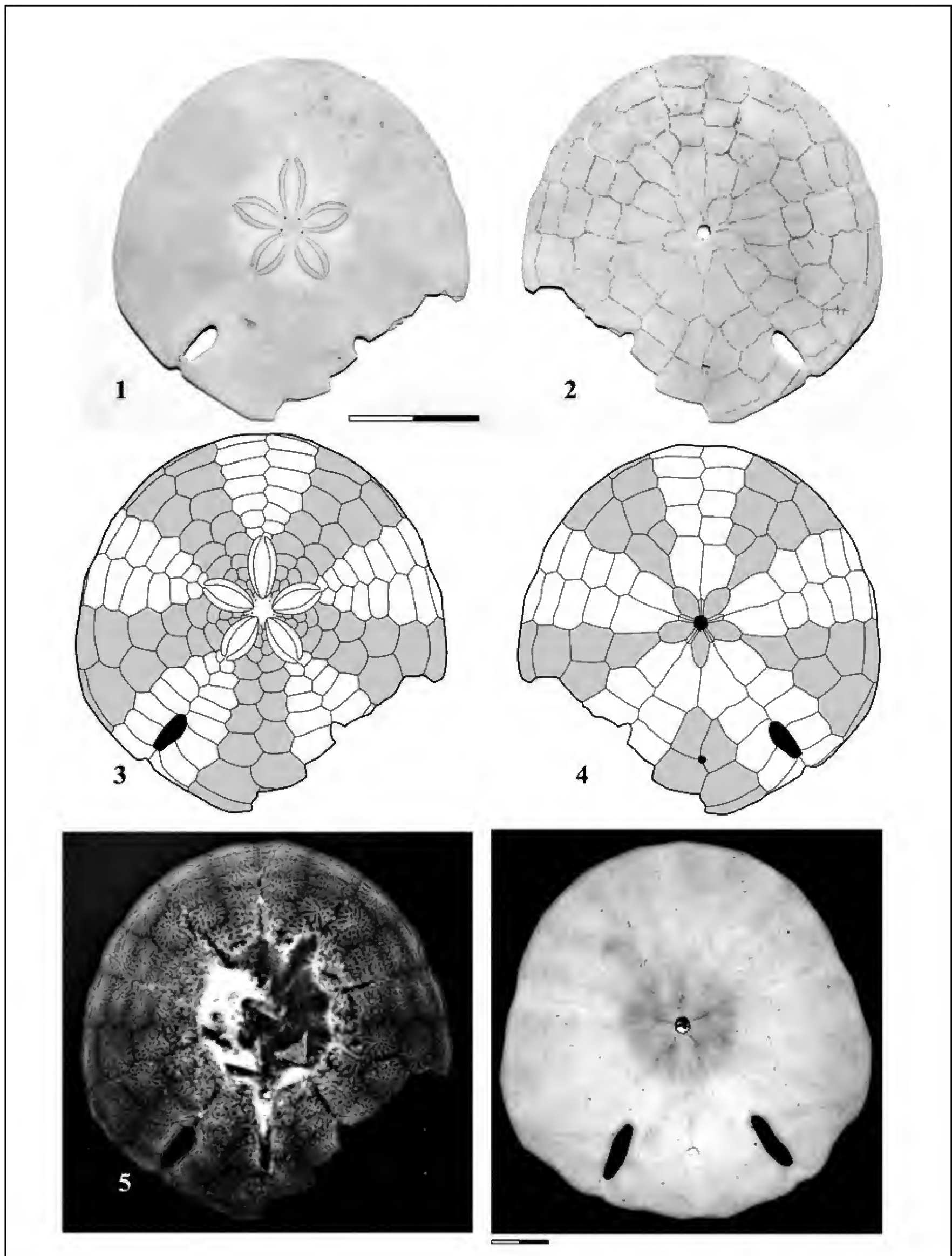2001, *Echinodiscus bisperforatus* Leske, 1778. Lindley, p. 128.

Plate 22. *Sculpsitechinus tenuissimus*, Recent, Lembeh (Indonesia) and New Caledonia. Figs. 1, 2. Aboral and adoral view of MAC.IVM207 from Lembeh, North Sulawesi, Indonesia. Figs. 3, 4. Plate pattern of aboral and adoral faces of MAC.IVM207. Fig. 5. Radiograph taken in supero-inferior position of MAC.IVM207; are visible the parts of the small Aristotle's lantern. Fig. 6. Aboral view of well preserved specimen from New Caledonia (F. Hattemberg collection).
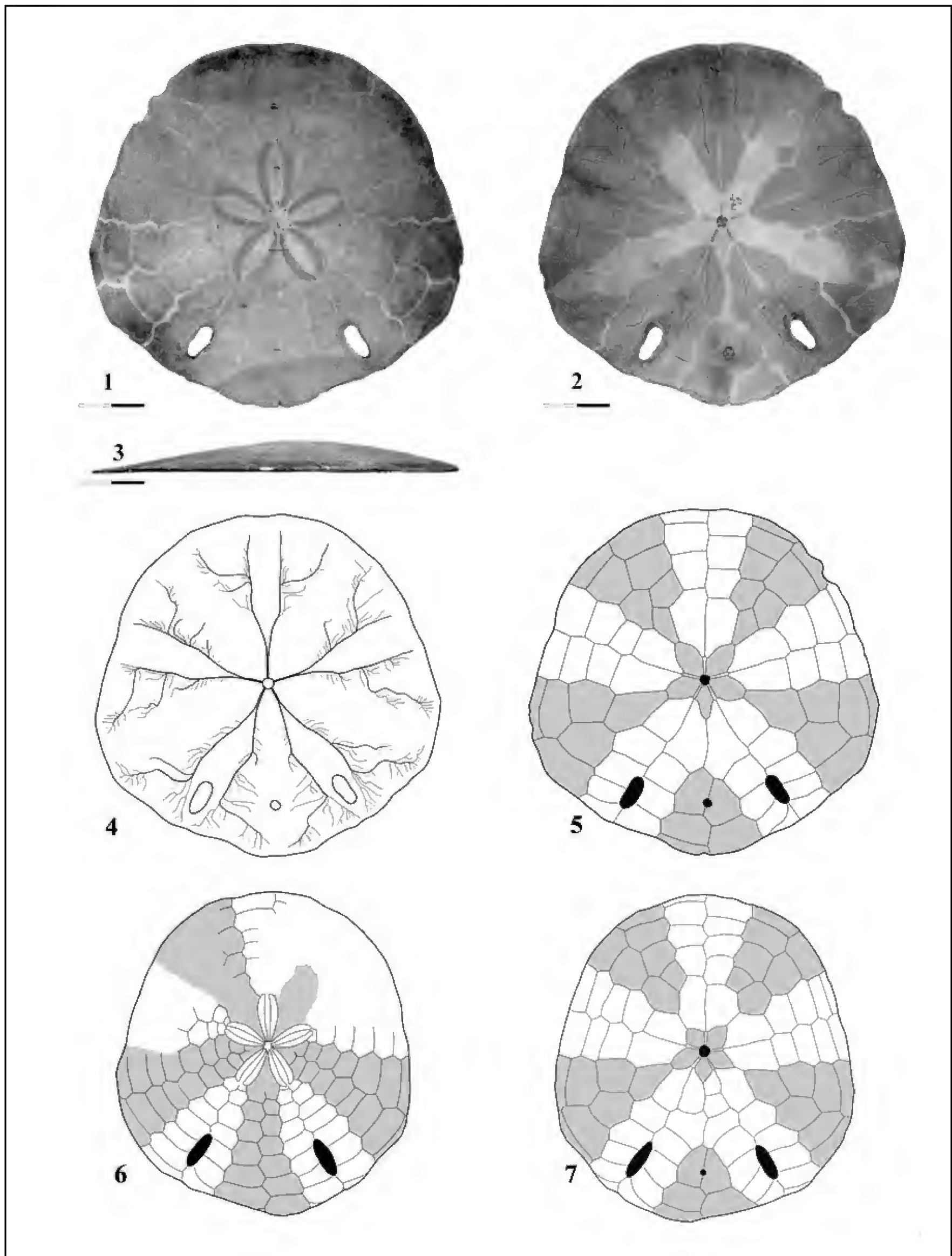
Plate 23. *Sculpsitechinus tenuissimus*, other example from New Caledonia. Figs. 1-3. Aboral, adoral and antero (to the left)-posterior (to the right) lateral view of NHMUK.1981.11.2.25. Fig. 4. Food grooves very branched scheme of NHMUK.1981.11.2.25. Fig. 5. Plate pattern of aboral face of NHMUK.1981.11.2.25. Figs. 6, 7. Aboral and adoral plate pattern from figs. 5-6, Pl. 33 in Dolfuss & Roman (1981).

EXAMINED MATERIAL. One specimen TL = 70 mm; TW = 65 mm, housed in the Departement of Geology, Australian National University of Camberra; code ANU 60549.

DESCRIPTION. Test depressed of medium size, discoidal with anterior semi-circular outline, truncated posteriorly. Central apical system not well legible. Petals straight, narrow, distinctly closed distally; PL medium (43% TL); poriferous areas slightly less than the width of interporiferous ones. Axial, narrow Lunules in the posterior ambulacra. Tuberculation not legible.

Given its general shape, its large distance separating the lunule from the respective petals tips, and given the small ß angle, this echinoid appears very near to *S. tenuissimus*.

Lindley (2001) accost this form to *E. truncatus* "*lunule length relative to test radius or petal length as a dignositic character. The possession of closed posterior lunules of a similar length to petals clearly indicates assignment of the Aseki specimen to* Echinodiscus bisperforatus *Leske, 1778. E. tenuissimus (L. Agassiz, 1847), a similar species in many respects, possesses lunules shorter than petals. Although Mortensen (1948: 409) observed that the length of lunules varies very considerably within this species, it is useful to note that the lunules of the Aseki specimen are at most about as long the petals, a diagnostic character of var. truncatus (L. Agassiz, 1841)*".

Besides, the size of the lunules (L1 = L2 = 15% TL and 2.8% TL and SI = 0.18) is different from that of *S. tenuissimus*, in which L1 = 12% TL and and L2 = 4% TL, with an SI = 0, 33. The data, however, is not sufficient to separate with certainty this species from *S. tenuissimus*. In fact, the features of the oral face and of the plate structure are unknown.

DISTRIBUTION. Langimar Beds, Middle Miocene, Aseki Village (Morobe Province), Papua New Guinea.

REMARKS. Based on its geological age, we believe that it is an ancestral species of *S. tenuissimus* and *S. auritus* currently living in the same regions. However, in the absence of further details such species is left in open nomenclature: *Sculpsitechinus* sp. 2.

ACKNOWLEDGEMENTS

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Taxonomic notes on the genus *Pseudoapterogyna* Escalera, 1914 (Coleoptera Scarabaeoidea Melolonthidae) in Sicily

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ABSTRACT   All Sicilian records of the genus *Pseudoapterogyna* Escalera, 1914 (Coleoptera Scarabaeoidea Melolonthidae) are revised. As a result four species are reported to occur in Sicily: *P. euphytus lamantiai* n. ssp. (for the populations of Pantelleria Island, previously attributed to *P. euphytus* s.l.), *P. vorax* (Marseul, 1878) from Lampedusa Island, *P. pellegrinensis* (Brenske in Ragusa, 1893) from Western Sicily (to which all *P. euphytus* records from Sicily need to be attributed), and *P. michaelis* n. sp. from Western Sicily.

KEY WORDS   Melolonthidae; *Pseudoapterogyna*; Sicily; taxonomy.

INTRODUCTION

The Sicilian *Pseudoapterogyna* Escalera, 1914 (Coleoptera Scarabaeoidea Melolonthidae) have been attributed thus far to *P. euphytus* (Buquet, 1840), a species deemed to occur through Algeria, Tunisia and Sicily (Rottenberg, 1871; Ragusa, 1873; 1874; 1893; Bertolini, 1899; Heyden et al., 1883; Luigioni, 1929; Porta, 1932; Baraud, 1977; 1985; 1992; Arnone et al., 1995; Carpaneto & Piattella, 1995; Sparacio, 1995; Smetana & Král, 2006; Arnone, 2010; Ballerio et al., 2010).

Examination of type material of *P. euphytus* plus a large quantity of specimens from Sicily and Northern Africa allowed me to re-evaluate the taxonomic status of the Sicilian populations of *Pseudoapterogyna*. As a result *P. euphytus euphytus* proved not to occur in Sicily, being restricted to Algeria and Tunisia, while the Sicilian populations of *Pseudoapterogyna* proved to represent three distinct taxa: *P. euphytus lamantiai* n. ssp. from Pantelleria Island (Sicily Channel), *P. pellegrinensis* (Ragusa, 1892) and *P. michaelis* n. sp., both endemics of North-Western Sicily.

I consider *Pseudoapterogyna* Escalera, 1914 as a separate genus (according with Baraud, 1985; 1992), and not as a synonym of *Geotrogus* Guérin-Méneville, 1842, as recently proposed by Coca-Abia (2003, see also Smetana & Král, 2006).

ACRONYMS AND ABBREVIATIONS. V. Aliquò collection, Palermo, Italy (CVA); M. Arnone collection, Palermo, Italy (CMA); M. Bellavista collection (CMB); Armando Monastra collection, Palermo, Italy (CAM); M. Romano collection, Capaci, Palermo, Italy (CMR); I. Sparacio collection, Palermo, Italy (CIS); A. Tetamo collection, Palermo, Italy (CAT); Collection of Dipartimento di Biologia Animale University of Catania, Italy (CMC); Collection of Museo Civico di Storia Naturale "Giacomo Doria", Genova, Italy (MCSNG); Collection of Museum National d'Histoire Naturelle, Paris, France (MNHN); m = male/s; f = female/s. Unless otherwise stated, the collector of the beetles in the field is the owner of the collection.

Pseudoapterogyna euphytus euphytus Buquet, 1840

EXAMINED MATERIAL. 1 ex labelled: Ex Musaeo Mniszech / a Euphytus Bqt alg. type / Museum Paris - ex coll. R. Oberthur / SYNTYPE - *Rhizotrogus euphytus* Buquet, 1840 / SYNTYPE / SYNTYPE - *Pseudoapterogyna euphyta* (Buquet, 1840) / MHNHN EC4183. 1 ex labelled: Ex Musaeo Mniszech / Museum Paris - ex coll. R. Oberthur / SYNTYPE - *Rhizotrogus euphytus* Buquet, 1840 / SYNTYPE / SYNTYPE - *Pseudoapterogyna euphyta* (Buquet, 1840) / MHNHN EC4184. Algeria, Costantine, Bonvouloir, 1 m (MCSNG); Algeria, Costantine, Henon, 3 m and 1 f (MCSNG); Algeria, Batna, 27 marzo 1952, ex coll. G. Fiori, 1 m (MCSNG); Algeria, Bône, 1874, Puton, 2 m and 2 f (MCSNG); Tunisia, Tunisi, Aut.-Inv. 1981-2, G. e L. Doria, 3 m (MCSNG); Tunisia, Tunisi dint., 1881, G. e L. Doria, 1 m

BIOLOGY AND DISTRIBUTION. Aduls often found under stones. Algeria and Tunisia.

REMARKS. *P. euphytus* was described from Constantine in Algeria (Buquet, 1840). The synonyms of this species are the following (Baraud, 1985; 1992; Smetana & Král, 2006): *maculicollis* Fairmaire nec Villa, 1860; *biskrensis* Marseul, 1878 locus typicus: Biskra, Algeria; *tuniseus* Fairmaire, 1884 locus typicus: Tunis, Tunisia; *dilutus* Fairmaire, 1860 locus typicus: Tunis, Tunisia.

The study of *P. euphytus* type material (Figs. 1, 2), and of several specimens from the type locality and other places in Algeria and Tunisia allows to summarize the diagnosis of this species (see also Baraud, 1985) as follows:

Males with fully developed metathoracic wings, females are flightless. Length 12–16 mm.; yellowish-brown, disc of pronotum sometimes darker; dorsal surface sub-opaque; antennae 10-segmented, scape elongate and dilated distally, club developed, shorter than funicle (club/funicle = 0.64); pronotum glabrous, only a few sparse short erect setae on anterior margin, surface micro-reticulated, punctation with large and dense punctures (the distance between the punctures being subequal or inferior to their diameter); posterior angles well marked, in most cases distinctly projecting backwards, preceded by a slight sinuosity at lateral sides; base of pronotum marked by a trasversal row of coarse punc-

tures; elytral surface densely microreticulated, with shallow and poorly defined puncturation. Anterior tibiae tridentate on external margin, basal tooth very short, sometimes absent. Posterior tibiae without carina on dorsal side or, at least, proximally. 1° metatarsomere short in both sexes. Claws toothed at base and with a spine well developed. Pygidium finely wrinkled and micro-reticulated with puncturation made of shallow scattered large punctures mixed to other much smaller and denser punctures. Posterior coxae of males far from median coxae. Aedeagus with parameres, in lateral view, narrowed distally with very elongate and pointed apex.

Females have a more convex dorsum, a smaller antennal club, shorter tarsi, posterior angles of pronotum often pointed, and larger and coarser elytral punctation.

Pseudoapterogyna euphytus lamantiai n. ssp.

EXAMINED MATERIAL. Holotypus male (CIS): Pantelleria (Sicily, Italy), Sesi, 10.V.1991, 1 m; Paratypes: ibidem, 30.IV.1995, 2 m and 4 f (CIS). Pantelleria, II.1906, S. Sommier, *Rhizotrogus euphytus* Buq., det. Sabatinelli, 4 m (MCSNG). 1 male labelled: "Pantelleria" and 1 male without label, likely from the same locality as above (see below) E. Ragusa collection (CMC).

DESCRIPTION OF HOLOTYPUS. Length 12 mm. Yellowish-brown, disc of pronotum sometimes dark brown; antennae, palpi, legs, pubescence, and ventral surface yellowish; dorsal surface subopaque. Head with deep and dense punctation and a thin, slightly raised transverse carina; clypeus slightly emarginate at middle of anterior margin. Antennae 10-segmented, club 3-segmented, about half the length of funicle (club/funicle = 0.52); scape dilated distally, almost as long as the 2°, 3° and 4° segments together. Pronotum with maximum width just before middle, sides crenulated, subrectilinear with a little sinuation before posterior protruding angles; anterior margin subrectilinear; basal bead complete, flattened and punctate; pronotal sculpturing made of middle-sized deep sparse punctures (the distance between the punctures being more than double their diameter) clearly visible on the micro-reticulated surface; the anterior margin and sides of pronotum bear short and sparse fine setae. Scutellum triangular, bearing some short

setae near base, with big shallow punctures. Elytra subparallel, slightly dilated at apical third, with micro-reticulated surface bearing some deep small punctures; humeral callus visible. Anterior tibiae tridentate, with a very weak hardly visible basal tooth. Posterior tibiae without carina on dorsal side. Tarsi about twice longer than tibiae. First posterior tarsomere shorter than the 3° tarsomere. Claws toothed at the base and with a spine well developed. Pygidium finely wrinkled, micro-reticulated, with punctures small. Metathoracic wings fully developed. Aedeagus with parameres strong, narrowed distally, with slightly elongate apex.

VARIABILITY. Length 11.5–13 mm; the disc of pronotum may be yellowish in colour, like the rest of the body. The little carina of dorsal side of posterior tibiae may be absent or very reduced. Females are flightless, have a more convex dorsum and elytra more dilated backward, with dorsal punctation sparse and shorter tarsi; posterior tarsi little longer than posterior tibiae.

ETIMOLOGY. Latin noun in the genitive case. After Tommaso La Mantia, University of Palermo, Italy, in acknowledgement of his oustanding expertise on the Sicily channel islands.

BIOLOGY AND DISTRIBUTION. Adults found under stones, active during Spring. Records from other seasons (see Arnone et al., 1995) are likely due to findings of dead specimens under stones, often found in good condition due to the dry environment. Endemic to Pantelleria Island.

COMPARATIVE NOTES. *P. euphytus lamantiai* n. ssp. differs from *P. euphytus euphytus* from Algeria and Tunisia by the following characters: smaller size, males with dorsum less convex, more parallel body (especially the elytra), punctation (in particular that of pronotum) sparser and less deep, antennal club longer, sculpturing of pygidium without big punctures, and shape of parameres with stouter and shorter apex.

REMARKS. All previous records from Pantelleria Island, such as Ragusa (1875: sub *Rhizotrogus Gerardi* Buq.), Bertolini (1899: sub *Rhizotrogus Gerardi* Buq.), Luigioni, 1929 (sub *Rhizotrogus euphytus* Buquet), Liebmann (1962: sub *Rhizotrogus*
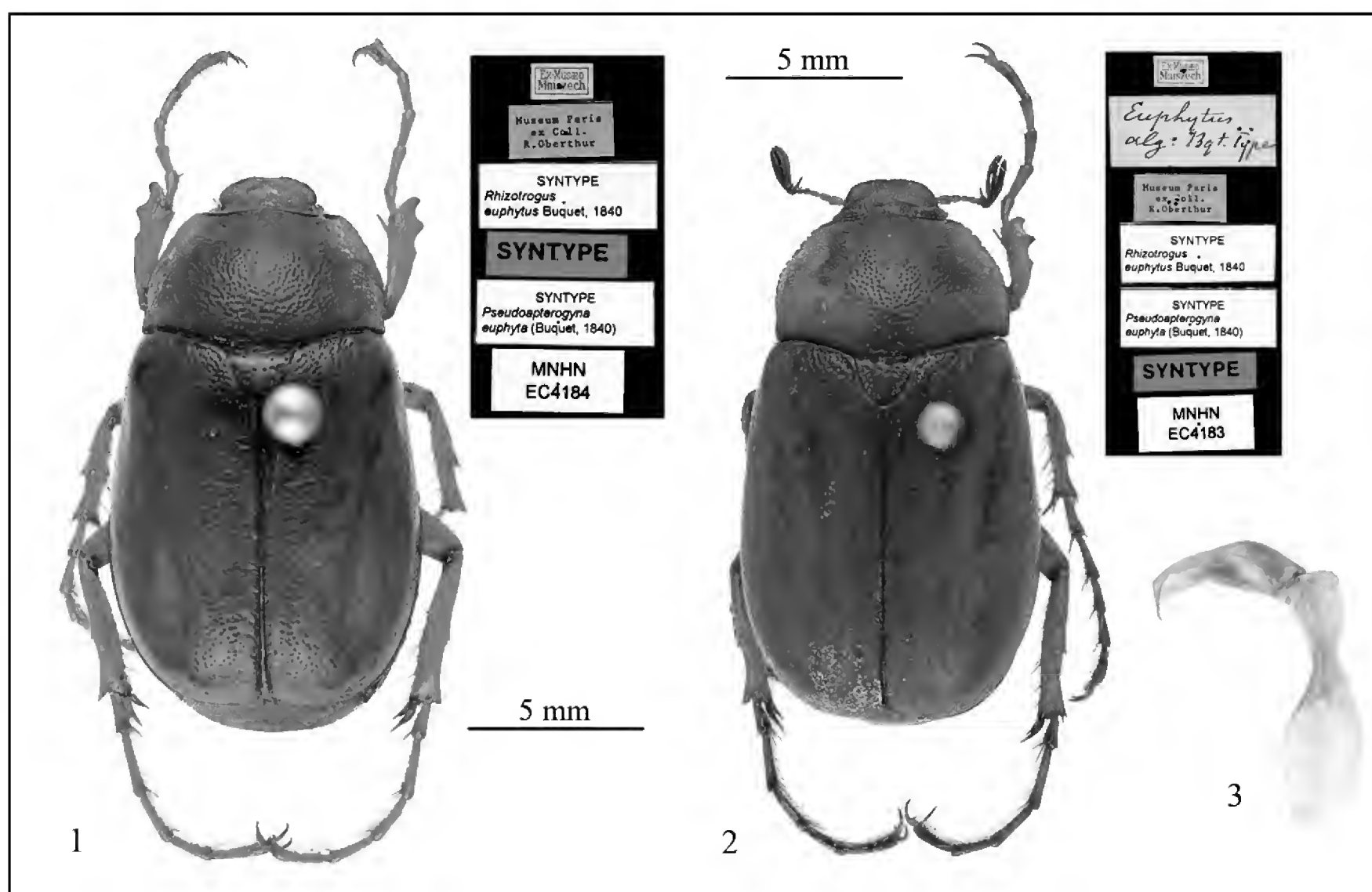
Figures 1, 2. Syntypes of *Pseudoapterogyna euphytus* (MHNHN).
Figure 3. Aedeagus of the *P. euphytus* from Costantine, Algeria, length 6.3 mm (MCSNG).

euphytus), Ratti, 1987 (sub *P. euphytus*) and finally Arnone et al. , 1995 (sub *P. euphytus*), actually refer to *P. euphytus lamantiai* n. ssp.

Pseudoapterogyna pellegrinensis (Brenske in Ragusa, 1893)

EXAMINED MATERIAL. Lectotypus male: Falde 3. [Monte Pellegrino leg. E. Ragusa], E. Ragusa collection (CMC); paralectotypes, idem 8 males and 3 females, without label, likely from the same locality as above (see below) E. Ragusa collection (CMC); Palermo, Addaura, 17.I.1970-10.II.1970 (CVA); Monte Cuccio (Palermo), 4.IV.1970-27.III.1971 (CVA); Cinisi (Palermo), 7.I.1973-11.II.1973-7 and 19.III.1973 (CVA); Capaci (Palermo), 11.II.1973 (CVA); Mazara del Vallo (Trapani), 16.IV.1976, 9.I.1983, 15.II.1983, 2.IV.1983, 13.V.1983, 6.XII.1986, 11.IV.1987 (CVA); Foce Fiume Belice (Trapani) 13.IV.1984 (CVA). Cinisi (Palermo), 11.II.1975 (CAM); Mazara del Vallo (Trapani), 6.II.1984 (CAM); Torretta (Palermo), 23.II.1977 (CAM). Capaci (Palermo) 9.I.1973, 8.II.1973, 6.III.1973, 27.I.1980 (CMR); Carini (Palermo), 7.III.1973 (CMR); Cinisi (Palermo) 19.III.1973 (CMR); Castelluzzo litorale (Trapani), 10.IV.2011 (CMR); Capaci (Palermo), 27.I.1980, 3.II.1980, 17.II.1980 (CMA); Cinisi (Palermo), 21.III.1986 (CMA); Palermo, Addaura, 23.XII.1972, leg. A. Carapezza (CMA); Campobello di Mazara: Cave di Cusa (Trapani), 7.IV.1985 (CMA); Castelluzzo litorale (Trapani), 14.III.1999, 17.II.2002, 10.IV.2011 (CMA); Isole Egadi, Favignana (Trapani), 30.IV.1969 leg. B. Massa (CMA); Mazara del Vallo (Trapani), 9.I.1983, 30.IV.1983 CMA). Palermo, Tommaso Natale, 23.III.1978, 1 m (CIS); Capaci (Palermo), 17.II.1980, 4 m and 3 f; idem, 16.I.1983, 1 m 10.V.1991, 1 m (CIS); Sferracavallo, La Conza, 18.I.1981, 2 f; idem 10.V.1991, 1 m (CIS); Mazara del Vallo (Trapani), 1.II.1981, 1 m (CIS); Isola delle Femmine (Palermo), 25.II.1983, 1 m 10.V.1991, 1 m (CIS); Cinisi (Palermo), 25.II.1983, 1 m 10.V.1991, 1 m (CIS); Terrasini (Palermo), 12. IV.1983, 1 m; idem, 24.IV.1993, 1 f; idem, 2.IV.2002, 1 f 10.V.1991, 1 m (CIS); Monte Cofano (Trapani), 14.IV.1991, 1 m (CIS).

BIOLOGY AND DISTRIBUTION. A Mediterranean maquis dweller, usually found in open disturbed maquis, with stony grounds. Adults of *P. pellegri-nensis* are found under stones, or walking, or (males only) flying during Spring months. Larvae are rizophagous and found underground. Endemic to North-Western Sicily, in strong rarefaction near Palermo where it has disappeared from many localities in the last thirty years; very localized in the area of Trapani.

COMPARATIVE NOTES. Compared to *P. euphytus*, *P. pellegrinensis* is bigger and wider (length 15–18 mm), shiny and has a less convex dorsum. Diagnosis: reddish-brown. Male: club/funicle = 0.52, pronotum wider just before anterior half, with punctures smaller, spaced and shallow, irregularly distributed, thinner at the sides; sides less curved, slightly sinuated just before posterior angles, posterior angles well-marked but not protruding. Elytra wrinkled, with irregular longitudinal striae, with hardly visible micro-retic-ulation and punctures big and deep. Posterior tibiae distinctly keeled on the dorsal surface. Ventrites shiny, the first three with a longitudinal depression. Pygidium much wider at base, coarsely wrinkled, micro-reticulated and with punctures small and very dense; apical margin slightly emarginate. Aedeagus with parameres stouter, slightly elongate distally.

Female: females are wingless, with a more convex dorsum and elytra more dilated backward; posterior tibiae distinctly keeled on the dorsal surface; posterior tarsi little longer than posterior tibiae.

REMARKS. In Sicily, *P. euphytus* was reported for the first time by Rottemberg (1871: "Am Fuss des M. Pellegrino") and mentioned several times by Ragusa (1873; 1874; 1893).

Ragusa (1874), however, was not convinced of the identity of this beetle "... *il Barone di Rottemberg ... lo crede il* R. Euphytus *Buq...Quest'insetto merita d'essere attentamente studiato ...*". ["Rottemberg ... he believes it is *R. euphytus* Buq. ... this insect deserves to be carefully studied"].

In his " Catalogo ragionato dei Coleotteri di Sicilia", Ragusa (1893) provided a long comment on *P. euphytus* in a footnote in which he translates a letter that he received from Brenske (to whom he had "*comunicato tutte le specie di* Rhizotrogus *di Sicilia*" ["sent all the species of *Rhizotrogus* of Sicily"]). Brenske, after examining the bibliography on *P. euphytus* available at that time, indicates that the Sicilian populations of the species should be distinguished from those of North Africa: "*(1) Var.* pel-

legrinensis *Brenske var. nov. ... esse si devono separare, se non come due specie distinte, una come varietà dell'altra.... La differenza più evidente sta nella punteggiatura del pygidio, che nell' insetto di Sicilia non è lucido, ed è leggermente aggrinzita, mentre l'algerino è oltre di ciò ricoperto di grossi e forti punti. Per la specie di Sicilia io scelgo il nome di* pellegrinensis*, per indicare la località dove questa specie è stata fin'ora trovata.*"

["(1) Var. *pellegrinensis* Brenske var. nov. ... they must represent two distinct species or at least two distinct varieties. The most obvious difference is in the punctation of pygidium, which in the insect from Sicily is not shining, and slightly wrinkled, while in the Algerian specimens, in addition to this character, is covered by big and strong punctures. For the species of Sicily I choose the name *pellegrinensis* to indicate the location where this species has been found so far."]

It is quite clear from the footnote of Ragusa's 1893 paper that the name "*pellegrinensis*" and the description come from Brenske. I think therefore that Brenske is alone responsible both for the name and for satisfying the criteria of availability other than publication, hence, according to art. 50.1.1 of the Code, Brenske is the author of the name "*pellegrinensis*", which needs to be quoted as Bresnke in Ragusa. Ragusa provided only the translation of Brenske's letter, but this circumstance, in my opinion, is not sufficient to change the sole responsibility of Brenske.

The populations of Sicily, so far reported as *P. euphytus*, show clear differences from *P. euphytus* and therefore must be attributed to *P. pellegrinensis*. Reports of *P. euphytus* from the Lampedusa Island (Failla Tedaldi, 1887; Heyden et al., 1891; Goggi, 2004) are likely records of *P. vorax* (see below).

In Ragusa's collection there are 14 specimens of *Pseudoapterogyna* from Sicily (see also Arnone, 2010); only two of them bear a locality label. One of them comes from Pantelleria (together with other two specimens of the series of 14 specimens) and therefore belongs to *P. euphytus lamantiai* (see above), while the other bears the following label:: "Falde, 3, E. Ragusa. [Monte
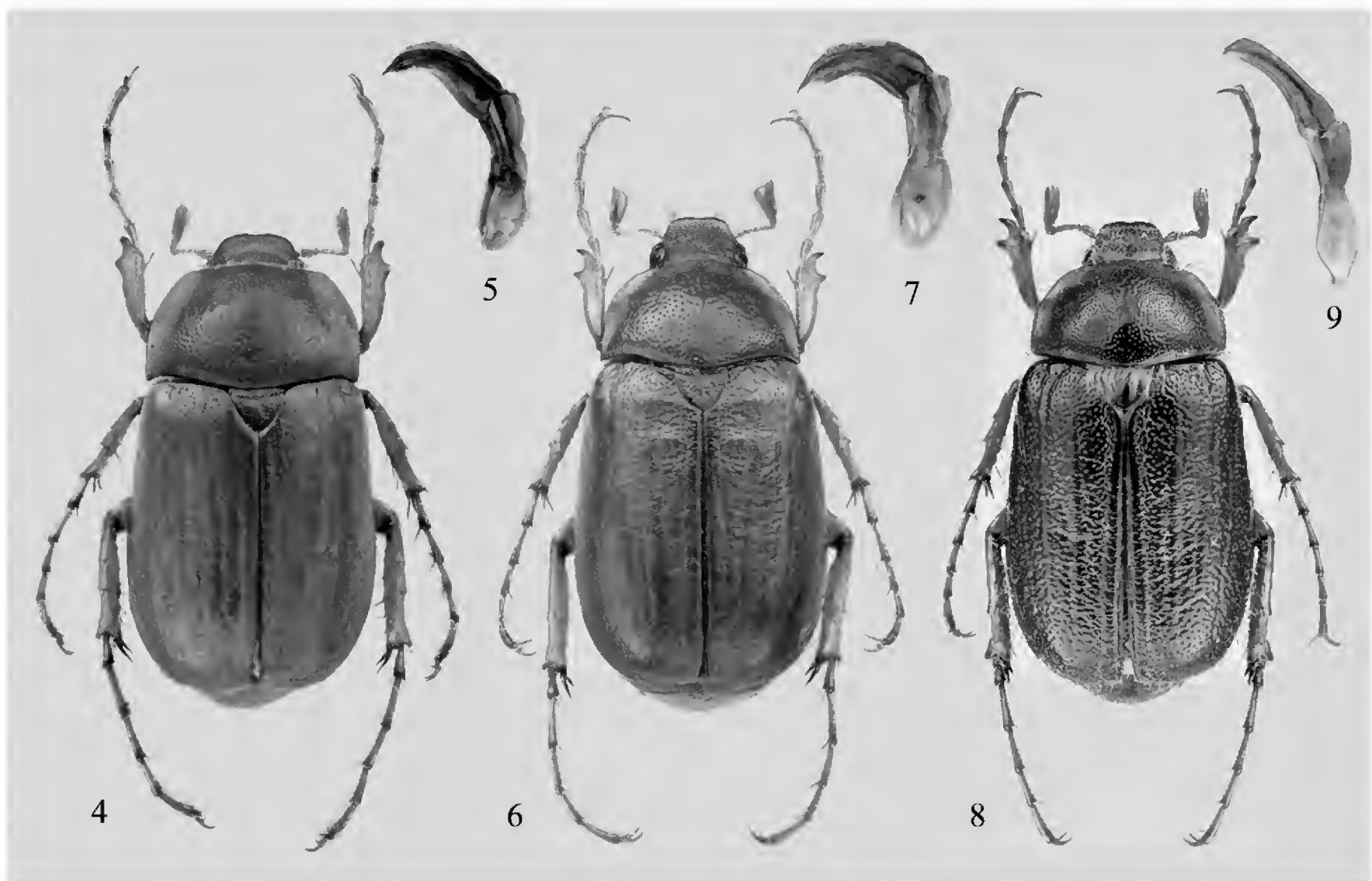

Figure 4. *Pseudoapterogyna euphytus lamantiai* n. ssp. Fig. 5. Idem, aedeagus, length 5.6 mm. Fig. 6. *P. pellegrinensis*. Fig. 7. Idem, aedeagus, length 6 mm. Fig. 8. *P. michaelis* n. sp. Fig. 9. Idem, aedeagus, length 6 mm. (photos M. Romano).

Pellegrino leg. E. Ragusa]" (foothills, March, E. Ragusa. [Monte Pellegrino leg. E. Ragusa]". I hereby designate this latter specimen as the lectotypus of *P. pellegrinensis*. The following red handwritten label has been added to it: Lectotypus - *Pseudoapterogyna pellegrinensis* Brenske in Ragusa, 1893, I. Sparacio des. 2014. Ragusa used to add the locality label only to the first specimen of a series (Arnone, 2010), therefore the remaining ten specimens of the series, all belonging to *P. pellegrinensis*, have to be consdiered as paralectotypi.

Pseudoapterogyna vorax (Marseul, 1878)

EXAMINED MATERIAL. Sicily (Agrigento), Lampedusa, 4.VI.1975, 1 m (*Pseudoapterogyna vorax* Mars. J. Baraud det.), legit B. Massa (CMA); idem, 1 f, 5.VI.1975 (CMA); Sicilia (Agrigento), Isola di Lampedusa, 15.V.1983, 1 f (CIS).

BIOLOGY AND DISTRIBUTION. Adults active in May and June. Records from other months (Arnone et al., 1995; Ballerio et al., 2010) are likely findings of dead specimens, often found under stones.

P. vorax is widespread from Morocco to Libia (Baraud, 1985). Baraud (1977) was the first to report the occurrence of this species in Lampedusa (Sicily Channel), later Smetana & Král (2006) added a record from Lampione (an islet next to Lampedusa).

REMARKS. A comparison between the holotype of *P. vorax* (MNHN, locus typicus: Algeria, Batna) and a few specimens from Lampedusa Island did not reveal any relevant difference between the two populations.

Pseudoapterogyna michaelis n. sp.

EXAMINED MATERIAL. Holotypus male: Monte Cofano (Trapani, Sicily, Italy), 20.XI.2011 (CIS). Paratypes: idem, 2 m (CIS); idem, 17.XI.2013, 31 m (CIS); idem, 20 m, legit A. Tetamo (CMB); idem, 8 m (CAT); idem, 1 m, legit I. Sparacio (MNHN); idem, 1 m, legit I. Sparacio (MCSNG).

DESCRIPTION OF HOLOTYPUS. Length 14.5 mm. Shiny. Reddish-brown, with darker pronotum; palpi, antennae, tarsi, lateral margins of pronotum, and underside yellowish-brown; long yellowish-brown erect setae are present around the body, denser

in the central part of both the anterior and posterior margins of pronotum, the latter having also a very dense tuft of long fine recumbent setae. Sternum with dense yellowish setation. Antennae 10-segmented; scape elongate and distally dilatate, almost as long as 2°–3° and 4° segments together; 2° segment very short; club shorter than the 7 previous segments together (club/funicle = 0.60). Clypeus with anterior margin emarginate at middle.

Head covered with big deep dense punctures; a small transverse carina slightly raised and not reaching the sides is present on clypeus. Pronotum transverse, 2.3 times wider than long, sides slightly curved at basal, norrowed distally, maximum width at basal half; posterior angles obtuse; anterior margin slightly curved forward, posterior margin projecting backward in the middle with basal bead thin and with sparse little punctures; a smooth longitudinal line is present in the middle of pronotum; pronotal surface smooth (not microreticulated), sculpture formed by medium sized deep dense punctures, regularly distributed over the entire surface (the distance between the punctures subequal to twice their diameter). Scutellum wide, subtriangular, with curved sides, micro-reticulated, with deep dense punctation, concentrated mainly at sides, covered by the dense recumbent long fine setation.

Humeral callus present. Elytra broad, dorsally flattened, wider at distal third, coarsely striated, with punctures large, dense and deep at the base then densely wrinkled at apical third; elytral apex slightly divergent. Pygidium with poorly defined shallow sparse punctures on densely micro-reticulated surface. Tarsal claws toothed at base. Anterior tarsi elongate, 1.75 longer than the corresponding tibiae. Anterior tibiae tridentate on external margin. Posterior tarsi elongate, 1.75 longer than the corresponding tibiae, 1° tarsomere distinctly shorter than the 3°. Posterior tibiae without carina on dorsal side. Metathoracic wings fully developed.

Aedeagus, in lateral view, with sub-parallel parameres, distally slightly wider, with apex short, sharp and slightly curved.

Female unknown.

VARIABILITY. Body length 13–18 mm; colour of the dorsal surface is sometimes much darker, with pronotum almost completely dark. In some specimens there is a short and weak carina on the top of the dorsal face of posterior tibiae.

Figure 10. Distribution of the Sicilian members of the genus *Pseudoapterogyna* and of *P. euphytus euphytus* in North Africa (rhombus). *P. euphytus lamantiai*: triangle; *P. pellegrinensis*: circles; *P. michaelis*: star; *P. vorax* (also in Morocco): squares.

ETIMOLOGY. Latin noun in the genitive case. This new species is dedicated to my friend Michele Bellavista (Palermo, Italy).

BIOLOGY AND DISTRIBUTION. All specimens collected were found still alive in potholes with water, during an Autumn sunny day without wind. *P. michaelis* n. sp. seems to be an Autumn species and is known only from the type locality in North-Western Sicily, where it occurs in sintopy with *P. pellegrinensis*, the latter being however a Spring species. The collecting locality is characterized by a stony landscape, with sparse small trees in a disturbed Mediterranean maquis.

COMPARATIVE NOTES. *P. michaelis* n. sp. differs from North African *Pseudoapterogyna* for the following characters (see also Baraud, 1985, pp. 413–415, in particular points 9 and 16): antennal club slightly shorter than funicle, shape and setation of pronotum (long fine setae along basal and fore margins), thin basal bead of pronotum finely and sparsely punctate, obtuse posterior angles of pronotum without sinuation, posterior tibiae without carina on dorsal side, shape of parameres.

REMARKS. Distribution of the Sicilian *Pseudoapterogyna* is showed in figure 10.

They can be easily identified using the following key:

1. Tarsal claws with a short basal tooth only..*P. michaelis*

- Tarsal claws with a distinct sharp tooth just above basal tooth..2

2. Sides of pronotum without sinuation just before basal angle, which is obtuse and rounded. Pronotum without distinctly crenulate lateral margins. Aedeagus with parameres not narrowed distally and apex very short (lateral view)............*P. vorax*

- Sides of pronotum with a sinuation just before basal angle, which is acute or at a right angle. Pronotum with distinctly crenulate lateral margins. Aedeagus with parameres distally narrowed (lateral view)...3

3. Dorsal surface shiny. Posterior tibiae with upper face longitudinally carinate. Pygidium coarsely wrinkled, micro-reticulated and with punctures small and very dense; apical margin slightly emarginate..................................*P. pellegrinensis*

- Dorsal surface sub-opaque. Posterior tibiae without carina on upper face, or with a slight carina limited to the proximal part. Pygidium with different surface sculpturing.....................4

4. Pigidial punctation made of mixed dense small punctures and sparser larger ones on a micro-reticulate background. Parameres with very long and sharp apex (lateral view)......*P. euphytus euphytus*

- Pigidial punctation made of small deep punctures on a coarsely wrinkled background. Aedeagus with parameres with apex short (lateral view)................................*P. euphytus lamantiai*

ACKNOWLEDGEMENTS

(Cefalù, Italy), M. Bellavista (Palermo, Italy), and, particularly, to A. Ballerio (Brescia, Italy), M. Arnone (Palermo, Italy), and M. Romano (Capaci, Italy) for support in the field and during the preparation of this paper.

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On the distribution of some Mediterranean *Cerithiopsis* Forbes et Hanley, 1850 (Caenogastropoda Cerithiopsidae)

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ABSTRACT   New records extend the distribution range of some *Cerithiopsis* Forbes et Hanley, 1850 (Caenogastropoda Cerithiopsidae): *C. ladae* Prkic et Buzzurro, 2007, *C. pulchresculpta* Cachia, Mifsud et Sammut, 2004 and *C. iudithae* Reitano et Buzzurro, 2006.

KEY WORDS   *Cerithiopsis*; Cerithiopsidae; distribution; Mediterranean Sea; new records.

INTRODUCTION

The genus *Cerithiopsis* Forbes et Hanley, 1850 (Caenogastropoda Cerithiopsidae) gathers a large pool of species consistently associated with sponges (Marshall, 1978), it appears heterogeneous and possibly polyphyletic (Cecalupo & Robba, 2010; Prkić & Mariottini, 2010; Modica et al., 2013). Currently the genus is intended conservatively and only recently some species have been assigned to the new genus *Nanopsis* Cecalupo et Robba, 2010 relying on subtle differences of the protoconch (Cecalupo & Robba 2010). Otherwise Scuderi & Criscione (2011) stated that the description of a new genus could not depend on protoconch features only.

In this respect more than 20 species of *Cerithiopsis* occurs in the Mediterranean Basin (Campani 2014, pers. comm.; Gofas, 2013; Gofas & Le Renard, 2014), many of which have been described during the past few years with apparently narrow ranges. Here we provide new data on distribution of three *Cerithiopsis* species recently described in order to give a little contribution to the knowledge of this complex group. A thorough global revision taking into account not only shell morphology but also anatomical and genetical features will be necessary to reveal the actual relationships among them.

MATERIAL AND METHODS

Cerithiopsis ladae Prkic et Buzzurro, 2007 from Ile Rousse and Livorno were collected by algal washing. *C. pulchresculpta* Cachia, Mifsud et Sammut, 2004 from Argentario by brushing *Posidonia* rhizomes. All other specimens were picked up from shell grit samples collected by SCUBA diving.

ACRONYMS. CA = collection P.G. Albano (Bologna, Italy); CB = collection S. Bartolini (Firenze, Italy); CP = collection A. Pagli (Lari, Pisa, Italy); CRL = collection L. Romani (Lammari, Lucca, Italy); CRA = collection A. Raveggi (Firenze, Italy); CSC = collection C. Sbrana (Livorno, Italy); CSF = collection F. Siragusa (Livorno, Italy); sh = empty shell(s); sp: specimen(s) collected alive.

RESULTS AND DISCUSSION

Cerithiopsis ladae Prkic et Buzzurro, 2007

EXAMINED MATERIAL. Ile Rousse (Corsica, France), 30 m, 1 sp (CB); Livorno (Tuscany, Italy), 0.5 m, 1 sh (CRA); Calafuria (Livorno, Italy), 31 m, 1 sp (CRA); Elba island (Livorno, Italy), 40 m, 1 sh (CB); Punta Ala (Grosseto, Italy), 0.5 m, 1 sh (CB); Palinuro (Salerno, Italy), 05-2006, 30 m, 1 sh (CSF); Lampedusa island (Agrigento, Italy), 60 m, 1 sh (CRA); Malta, 60 m, 1 sh (CSC).
C. ladae "ribbed form": Cannizzaro (Catania, Italy), 40 m,1 sh (CB); Getares (Algeciras, Spain), 15 m, 1 sh (CB).

REMARKS. The present species (Figs. 2–5) has a dark brown, pupoid shells with a blunt cylindrical protoconch, smooth and white. It was described from Dalmatian coast (Prkić & Buzzurro, 2007) and subsequently recorded from Spain (Peñas et al., 2006; Oliver, 2007; Gofas et al., 2011; Oliver et al., 2012), Brindisi, E-Apulia (Scuderi & Terlizzi, 2012) and Eastern Sicily (Scuderi & Criscione, 2011). Our records extend its range to the Tyrrhenian Sea and Strait of Sicily.

We would like to take the opportunity of signaling some specimens from Cannizzaro (Sicily) and Getares (S-Spain) with axial riblets on the lower whorl of the protoconch (Figs. 4, 5). This feature wasn't reported in the original description but it was already noticed (Prkic 2008, pers. comm.). It confirms that the protoconch variability in *C. ladae* is wider than previously recorded, both in sculpture and in whorls morphology.

Cerithiopsis pulchresculpta Cachia, Mifsud et Sammut, 2004

EXAMINED MATERIAL. La Herradura (Granada, Spain), 30 m, 1sh (CRA); Ile Rousse (Corsica, France) 40 m, 2 shs (CB); Castelsardo (Sassari, Italy), 45 m, 2 shs (CB); Calafuria (Livorno, Italy), 31 m, 3 shs (CB); Capraia island (Livorno, Italy), 70 m, 1 sh (CP); Capraia island (Livorno, Italy), 31 m, 1 sh (CRL); Giannutri island (Grosseto, Italy), 55 m, 1 sh (CRA); Secca delle Murelle (Viterbo, Italy), 27 m, 1 sh (CSC); Punta Campanella (Naples, Italy), 50 m, 1 sh (CB), 1 sh (CRA); Palinuro (Salerno, Italy), 50 m, 1 sh (CB); Palinuro (Salerno, Italy), 30 m, 1 sh (CSF); Prvić island (Krk, Croatia), 40 m, 2 shs (CB); Corfu island (Greece), 15 m, 1 sh (CB); Corfu island (Greece), 58 m, 1 sh (CRA).

REMARKS. The species (Figs. 6, 7, 11, 12) has a brown conical-pupoid shell with a cylindrical bicarinated protoconch, crossed by close thin and dense axial riblets, hazelnut brown- hazelnut in colour. The present species was described from Malta (Cachia et al., 2004) and then reported from Calabria (Vazzana, 2010) and Sicily (Scuderi & Criscione, 2011). Our records widely extend its range to the north-central Tyrrhenian Sea, Corsica, Sardinia, NE Adriatic, NE Ionian and S Spain.

Cerithiopsis iudithae Reitano et Buzzurro, 2006

EXAMINED MATERIAL. Calafuria (Livorno, Italy), 31 m, 1 sh (CRA); Elba island (Livorno, Italy), 40 m, 1 sh (CB); Argentario (Grosseto, Italy), 15 m,1 sh (CA); Secca delle Murelle (Viterbo, Italy), 27 m, 1 sh (CSF); Punta Campanella (Naples, Italy), 50 m, 1 sh (CB); Prvić island (Krk, Croatia), 40 m, 1 sh (CB).

REMARKS. The species (Figs. 9, 10) has a brown conical-pupoid shell with a white protoconch sculptured by two spiral chords crossed by thin and undulated axial riblets. It was described from eastern Sicily (Reitano & Buzzurro, 2006) and then reported from Apulia (Trono & Macrì, 2013). Our records extend its range to the Tyrrhenian Sea and NE Adriatic.

The difficulty to correctly recognise many different species, which share a close similar teleoconch and protoconch morphology, is often due to the general status of the collected specimens. If they are not found in perfect conditions, important characters, as the protoconch morphology, could not allow the identification of the materials collected. Moreover the particular habitat and the small size of all the species of this family of gastropods has probably contributed to misidentifications and lack of data of many species. Putting together all these facts, in our opinion new examinations of specimens of collectors and further collecting materials could lead researchers to re-evaluate the distribution range of many species and their real diffusion status.
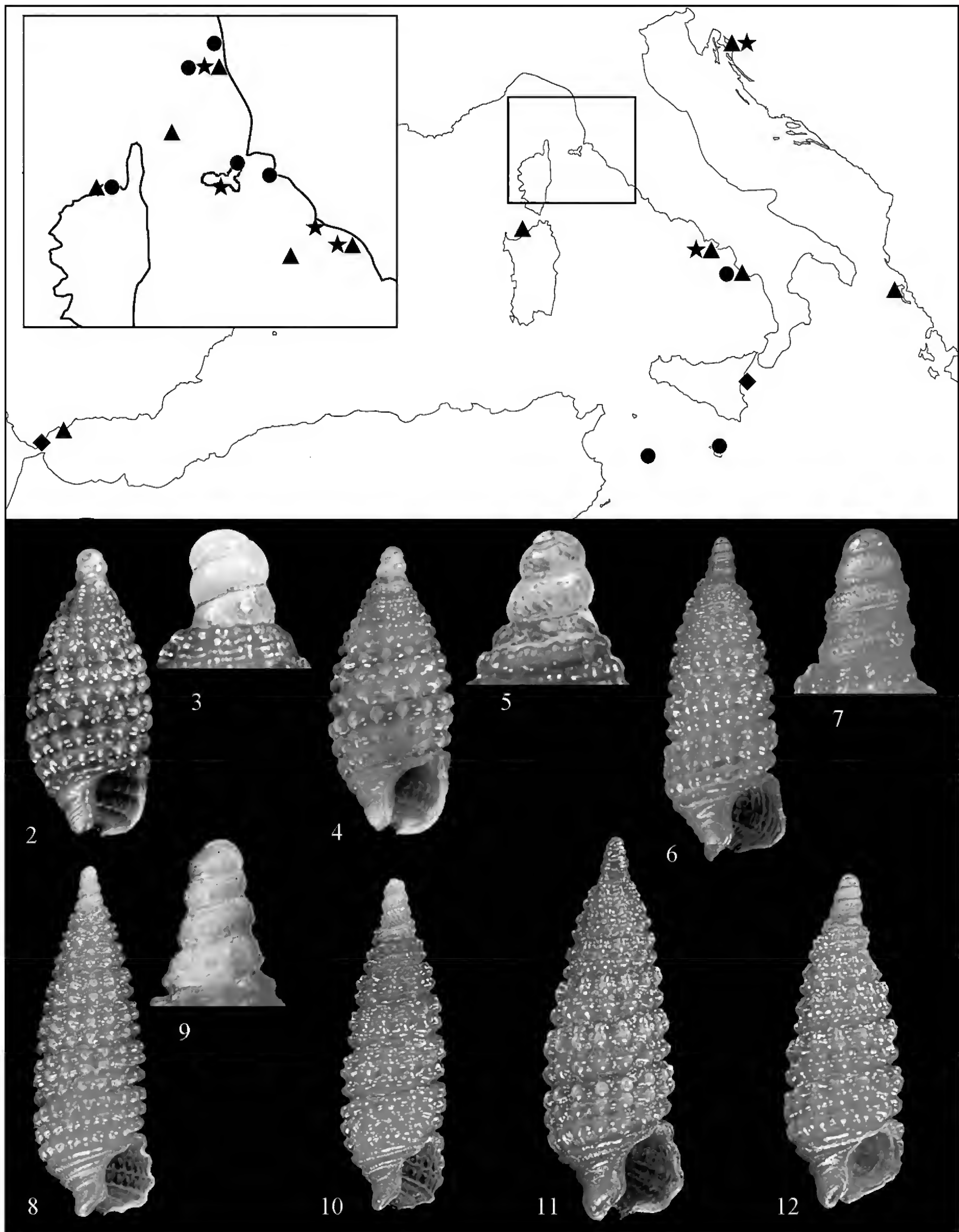
Fig. 1. Sampling localities of *Cerithiopsis iudithae* (black stars), *C. ladae* (black circles), *C. ladae* "ribbed form" (black diamond), *C. pulchresculpta* (black triangles). Figs. 2, 3. *C. ladae* and protoconch, Ile Rousse, Corsica, France, 2 mm. Figs. 4, 5. *C. ladae* "ribbed form" and protoconch, Getares, Spain, 1.9 mm. Figs. 6, 7. *C. pulchresculpta* and protoconch, Calafuria, Tuscany, Italy, 2.8 mm. Figs. 8, 9. *C. iudithae* and protoconch, Punta Campanella, Naples, Italy, 2.9 mm. Fig. 10. *C. iudithae,* Prvić, Croatia, 2.8 mm. Fig. 11. *C. pulchresculpta*, La Herradura, Spain, 3.2 mm. Fig. 12. *C. pulchresculpta* (Prvić, Croatia), 2.8 mm.

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Rediscovery of the critically endangered cyprinid fish *Epalzeorhynchos bicolor* (Smith, 1931) from West Thailand (Cypriniformes Cyprinidae)

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ABSTRACT   In the present paper, we report on the critically endangered cyprinid fish, *Epalzeorhynchos bicolor* (Smith, 1931) "rediscovered" in Maeklong Basin, West Thailand. Moreover, distribution data and biological observations of this species are also provided.

KEY WORDS   *Epalzeorhynchos bicolor*; Cyprinidae; Maeklong Basin; Thailand.

INTRODUCTION

The freshwater cyprinid fish genus *Epalzeorhynchos* Bleeker, 1855, order Cypriniformes Bleeker, 1859 and family Cyprinidae Cuvier, 1817, has been reported for Southeast Asia only (Kottelat & Whitten, 1996; Doi, 1997; Monkolprasit et al., 1997; Yang & Winterbottom, 1998).

According to the current taxonomic status of this genus, it comprises 4 valid species:

E. frenatum (Fowler, 1937) from Chao Phraya Basin, Maeklong Basin in Thailand and Mekong Basin in Indochina;

E. kalopterum (Bleeker, 1850) from South Thailand to Indonesia;

E. munense (Smith, 1934) from Mekong Basin in Indochina;

E. bicolor (Smith, 1931) from Central and West Thailand (Smith, 1931; Vidthayanon et al. 1997; Kottelat, 2013).

RESULTS

The cyprinid fish *Epalzeorhynchos bicolor* (Fig. 1) is an endemic fish of Thailand. The distribution of this species is reported only for Lower Chao Phraya Basin, Bangpakong Basin and Lower Maeklong Basin (Smith, 1931; Vidthayanon et al., 1997; Vidthayanon, 2005, 2011). It has been threatened by mass collecting for aquarium trade, pollution of many sources and habitats destruction (Vidthayanon, 2011) and, according to the IUCN Red List of Threatened Species (Vidthayanon, 2005, 2011), this fish is a threatened species. In 1996, it was even thought to be extinct in the wild since there was no documented evidence of it the last more than 50 years (Kottelat & Whitten, 1996).

Currently, the status of the species is poorly known. In 2011, Dr. Chavalit Vidthayanon assessed that the species is still extant in the Chao Phraya

Figure 1. *Epalzeorhynchos bicolor* from Maeklong Basin, West Thailand, standard length 66 mm.

Basin but strictly localized, nevertheless, its location is still unclear (personal comment). On the contrary, in the same year, the population of *E. bicolor* was reported to be extirpated in Maeklong Basin and Bangpakong Basin (Vidthayanon, 2011).

In a survey project of the first author at Lower Maeklong Basin, West Thailand (carried out during February 2013) the author found only one specimen of *E. bicolor* in the rocky dam around the mainstream of Maeklong River near the water gate of Maeklong Dam, Muang District, Kanchanaburi Province, Lower Maeklong Basin, West Thailand (Fig. 2).

This fish lives in gaps between the rocks and its habitat is characterized by large rocks and a sandy bottom. This area is fast flown by tides and the depth of water is more than 1 meter. In the same area, we found many other fish species, including:

CLUPEIFORMES CLUPEIDAE
Clupeichthys goniognathus Bleeker, 1855

OSTEOGLOSSIFORMES NOTOPTERIDAE
Notopterus notopterus (Pallas, 1769)

CYPRINIFORMES CYPRINIDAE
Rasbora aurotaenia Tirant, 1885
Barbonymus schwanenfeldii (Bleeker, 1854)
Cirrhinus molitorella (Valenciennes, 1844)
Opsarius koratensis (Smith, 1931)
Mystacoleucus marginatus (Valenciennes, 1842),
Osteochilus vittatus (Valenciennes, 1842)
Osteochilus microcephalus (Valenciennes, 1842)

CYPRINIFORMES BALITOLIDAE
Nemacheilus masyae Smith, 1933
Homaloptera smithi Hora, 1932

CYPRINIFORMES COBITIDAE
Acanthopsoides gracilentus (Smith, 1945)
Pangio oblonga (Valenciennes, 1846)

SILURIFORMES BAGRIDAE
Pseudomystus siamensis (Regan, 1913)

BELONIFORMES HEMIRAMPHIDAE
Dermogenys siamensis Fowler, 1934

SYNBRANCHIFORMES MASTACEMBELIDAE
Mastacembelus favus Hora, 1924

PERCIFORMES NANDIDAE
  Pristolepis fasciata (Bleeker, 1851)

PERCIFORMES AMBASSIDAE
  Parambassis siamensis (Fowler, 1937)

CONCLUSION

In conclusion, at present, the occurrence of *E. bicolor* in the wild is certainly confirmed in Lower Maeklong Basin, Kanchanaburi Province, West Thailand, whereas it is still unclear in the Chao Phraya Basin due to the lack, to date, of documented evidence.
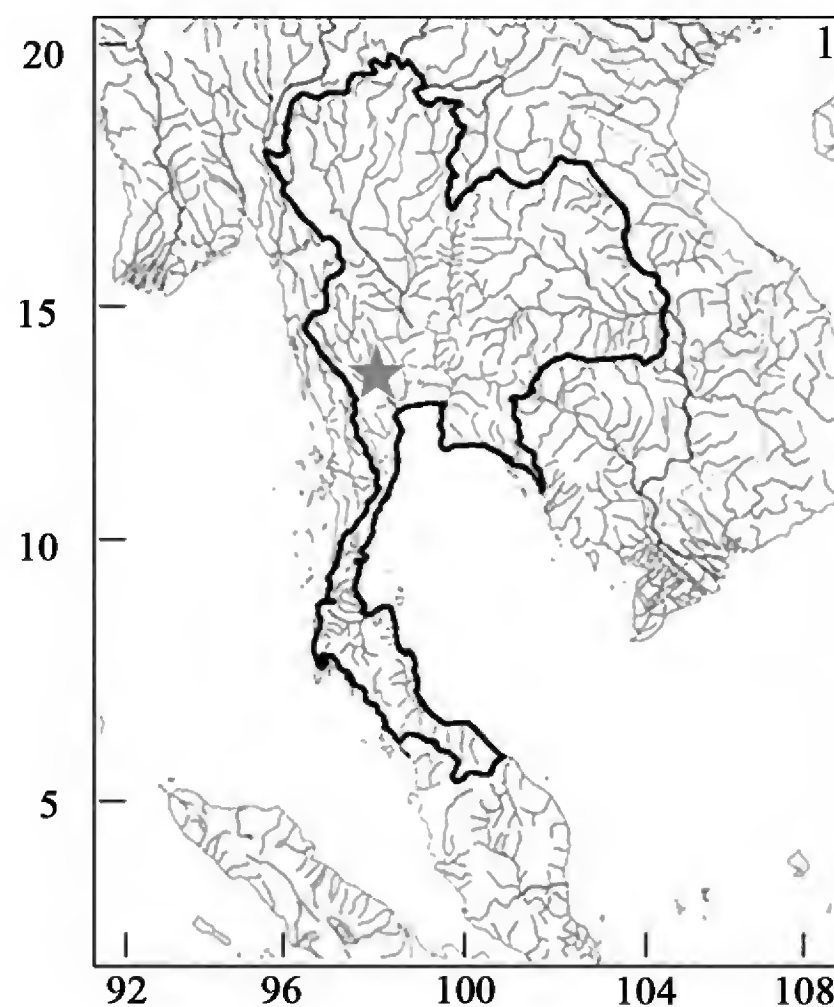

ACKNOWLEDGMENTS

Figure 2. Study area: Lower Maeklong Basin, Kanchanaburi Province, West Thailand.

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